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SUMMARY OF GOLDENROD INVESTIGATIONS AT U. S. PLANT INTRODUCTION GARDEN, SAVANNAH, GEORGIA, 1934 - 1940

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S (YU)
PLANTING
Nurseries
Goldenrod

October 20, 1942

Summary of Data by Subjects

Date of Planting: November 15 to April 1 shows no difference in yields. Soil moisture must be sufficient to promote root growth.

Vegetative Propagation:

1. Stolons. Furrow four to five inches deep, set the stolons at about two to three inches deep, firm the soil around each plant.

2. Rooted cuttings are planted in a similar manner, soil firmed around each plant.

3. One bushel of stolons will provide enough plants for 800 feet of row.

Seed Propagation:

1. Shallow planting in flats or fine soil. Fine spray is essential to prevent uncovering seed. Sow seed in January for transplanting in March. Space at 2 x 3 inches. High mortality in naked root planting from germinating flat to transplant bed. Part of the soil should be lifted with the roots.

Spacing and Yields: Initial plantings 30 to 36 inches center to center, and 8 to 12 inches in the row fits machinery and Southern agricultural practices. Closer spacing yields greater amount of leaves.

Second year fields lose row identity from stolon growth spreading between the planted rows.

Higher yields obtained from thickly planted or second year fields. Probably twice as much rubber per unit of area secured from two-year-old plantings.

Fertilization: Higher yields of rubber can be obtained from fertilized plots but the cost is not commensurate with results. Heavy applications of nitrogen or vigoro increased yields 9.5 pounds per acre, but at a cost of $25.00. Stolon production increased by fertilizer subsequent to cutting the stems.

Cultivation: No specific cultivation experiments have been conducted. Cultivation similar to cotton sufficient. Flat cultivation without hilling best for stolon production. Cutting weed growth within the row only hand hoeing necessary. Weeds eliminated to prevent normal development and interfere with the harvesting all that is needed. No cultivation

second year. Disking or other disturbances not beneficial to the established plants.

Date of Harvest: Early October is the most desirable time to harvest goldenrod leaves. Loss of leaves on the lower stems reduces the yields, but may be harvested to mid-November. Approximately a six-week period is all that can be expected.

Management and Yield of Perennial Plantings: Conclusive data on the technique of handling goldenrod as a perennial crop is not available. Small plots show:

1. Higher rubber yields the second year are obtained in every instance.

2. No cultivation necessary or desirable except possibly to eliminate high grass and weeds interfering with harvesting methods.

Selection and Breeding: Breeding work for the purpose of improving rubber yielding capacity of goldenrod has been carried on at Savannah from 1934 to 1940. Earlier work consisted of mass selection with 99 new varieties having been originated. Cross breeding the past two years has been between varieties having heavy leaf yield and high rubber content.

Variety Testing: Technique employed - single row comparisons, randomized replicated blocks. Many different species of goldenrod have been proved equal to S. leavenworthii as a rubber producer for the Savannah locality. A total of 200 different varieties of leavenworthii which were obtained from sources, and nearly 100 selections originated at Savannah have been studied during the seven-year period. All but 15 varieties have been eliminated for one reason or another and three of the 15 have proved to be definitely superior.

Insects and Diseases: Cultivated goldenrod is attacked by relatively few insects and is resistant to most diseases that actually kill the plant. Two species of Lepidopterous stem borers which hollow out the center of the stem affect the plants. Eggs deposited inside the stem a few inches below the terminal. Temporary wilting follows, but the plant usually recovers and makes comparatively normal growth. Stem breaking sometimes follows. Insect attacks vary from year to year. Common aphids are found but apparently do not cause serious damage. Red spiders in unusually dry weather sometimes attack goldenrod, but are not serious enough to cause permanent damage. Slower growth the most noticeable condition. Sulphur dust to the underside of the leaf controls the pest.

All species of goldenrod affected by the so-called scab disease. Elsinae Saledaginis, a fungus of the ascomycete class. This may happen at any stage of its development with young plants killed and larger ones definitely stunted. Characteristic corky lesions are formed principally on leaves, branches and inflorescences, and on severe cases considerable portions of the main stem are completely girdled. S. leavenworthii is almost never affected. Scab is effectively controlled by lime sulphur or sulphur dust.

"Blight" or root rot is the only known disease capable of causing serious losses. In unfavorable seasons this disease may cause as high as 15% reduction of stands. The causal organism is not definitely known since both fusarum fungus and nematodes are usually present in the diseased tissue. Brownish discoloration of the stem first noticed. The disease is then in the advanced stage. Patches of the field circular in shape and usually with sharp lines of demarkation are found in heavily infected field. "Blossom Blight" caused by fusarum affects the flowers. They fail to open naturally and show a brown discoloration. This is not important.

DATE OF PLANTING

An experiment was conducted during the 1935-6 season to compare the yield and rubber content of fall planting with the comparable yields of plants set out in the spring. In 1937 plantings were made on four different dates during the fall and spring to determine the optimum planting time.

The comparison in 1936 was confined to rooted stolon cuttings only. Planting dates compared were December 18 and March 26.

There was some indication that fall planting was more desirable where rooted stolon cuttings are used, but statistical significance could not be demonstrated due to lack of replications.

In the 1937 planting, the stolon cuttings used were not rooted previous to setting in the field. In this experiment, too, the results seemed to indicate some advantage for fall planted material, both cuttings and shoots, but analysis of the data showed no statistically significant differences in either yield of leaves or rubber content. (See Table I)

Since this latter experiment was carried out under ideal conditions with proper randomization, and an adequate number of replications, it is probably justifiable to conclude that date of planting is relatively unimportant so long as it is confined to the fall, winter or early spring months.

Late spring and summer plantings have been made too, but with considerably more difficulty and lower survival rate, because high temperatures and rapid drying of the topsoil render it extremely difficult to maintain optimum soil moisture conditions.

Cold injury to young plants is a factor that does not have to be taken into condition, as goldenrod has proved to be entirely hardy in this latitude. Rooted stolon cuttings have been taken direct from the greenhouse to the open field in December and survived a minimum of + 19°F without damage.

TABLE I

Rubber percent, Dry weight of leaves per plant, and rubber per plant of S. leavenworthii 573-F, Grown from Two Types of Propagating Material, Planted on four different Dates, and Harvested September 27, 1937.

(Figures Represent Mean of Six Replications)

	Planted: Nov. 15	Planted: Dec. 15	Planted: March 1	Planted: April 1
Rubber percent				
Shoots	5.84	5.46	5.42	5.23
Cuttings	5.54	5.44	5.23	4.98
Dry Wt. of Leaves per plant (Grams)				
Shoots	8.78	7.77	7.35	6.83
Cuttings	8.43	8.48	7.50	9.47
Rubber per Plant (Grams)				
Shoots	.517	.430	.398	.362
Cuttings	.460	.465	.397	.457

Note: There is no significant difference between means that could be attributed to different date of planting.

VEGETATIVE PROPAGATION

Nearly all species of goldenrod produce numerous, specialized, underground branches of the stem, which are known as stolons. These stolons may be from an inch or two to several feet in length. Their function is primarily reproductive, and each one normally sends up at least one shoot. The shoots are usually produced at the terminus of the stolon, and it is quite common for the stolons to branch repeatedly and to produce a shoot at the end of each branch.

These stolon shoots are the material most commonly employed in the vegetative propagation of goldenrod. They are removed from the parent plant by severing the stolon in such a manner that a segment of stolon 2 or 3 inches in length remains attached to the shoot. This stolon piece facilitates planting operations and increases the probability of survival.

Stolon cuttings may also be utilized for propagating goldenrod asexually, as there is a bud at each node of a stolon, and each bud is theoretically capable of developing into a new plant. A stolon cutting may consist of a single node, or more than one node, but polynode cuttings at least 3 or 4 inches in length have proved more satisfactory than the smaller ones.

It has been demonstrated that stolon cuttings produce equally good plants regardless of which part of the stolon the cuttings are taken from. Cuttings which included the growing point at the extremity of the stolon farthest from the old plant were found to sprout somewhat earlier than cuttings made from other portions of the stolon, but did not produce significantly better plants at maturity.

It has been observed that normal plants of Solidago Leavenworthii usually produce from 10 to 30 stolon shoots each, although some varieties are considerably more prolific than others. Approximately 50 polynode stolon cuttings may be obtained from an average plant of S. leavenworthii.

Solidago sempervirens and a few other species which are of minor importance from the standpoint of rubber production do not produce stolons, but may be propagated vegetatively by division of the crown.

A preliminary experiment for the purpose of testing the value of different types of vegetative propagating material for direct field planting was conducted in 1935 with the following species: Solidago leavenworthii, S. nashii S. fistulosa, S. altissima, S. edisoniana, S. serotina, and S. rugosa. Weather conditions were very unfavorable at planting time and the results were not conclusive. Only the stolon shoots produced a satisfactory stand. The stolon cuttings were almost a total failure in all species except leavenworthii and nashii, and in these species the cuttings produced poorer stands than the stolon shoots.

The one and two node cuttings proved much inferior to the longer cuttings which had five or more nodes.

A similar experiment was conducted in 1936 with Solidago leavenworthii, S. edisoniana, S. altissima, S. fistulosa, and S. serotina, which included, in addition to the comparisons between stolon cuttings and stolon shoots, a series of blocks in which the stolon shoots were drastically pruned at planting time.

In both leaves per plant and rubber per plant, the yield (mean of 5 species) of unpruned stolon shoots was significantly higher then the yield of either pruned stolon shoots or polynode cuttings. The two latter were not significantly different from each other in yield of either leaves per plant or rubber per plant.

The single node cuttings made a very poor showing and cannot be considered a satisfactory type of material for goldenrod propagation.

A randomized, replicated experiment for the purpose of comparing the yield of goldenrod plants propagated from stolon shoots with the yield of plants propagated from stolon cuttings was carried out at Ford Farms, Ways Station, Ga., in 1937. The selection used was Solidago leavenworthii 573-F. In this experiment plantings of both shoots and cuttings were made on four dates, November 15, December 15, March 1, and April 1, in order to ascertain the optimum planting time for the two types of propagating material. Statistical analysis of the data showed no significant differences between stolon shoots and cuttings in either leaf yield or rubber content.

Stolon cuttings may be rooted readily in a greenhouse or cold frame in moss or sand, about two months being required to grow a plant to a size suitable for transplanting to the field. They may also be

rooted successfully in unprotected beds if a constant supply of moisture is available.

An experiment in which rooted stolon cuttings (both fall-and spring-planted) were compared with spring-planted stolon shoots indicated that the rooted cuttings are at least equal, if not superior, to the stolon shoots in yield of rubber per plant. Definite levels of significance could not be established, however, due to lack of replications in this experiment.

Several methods of setting out stolon shoots into the field have been tried. The use of garden trowels to dig individual plant holes is perfectly satisfactory, but very slow. Plants may be dropped in a furrow and covered with a small moldboard plow or similar implement, but it is necessary that the dirt be firmed around each plant by hand after the mechanical covering. It was found that the percent survival of plants not firmed by hand after covering was significantly lower than that of control plants that had been so firmed.

A rapid and efficient method of setting out stolon shoots, and the one which has been adopted as standard practice in planting the Savannah experimental plots, consists of running a small horse-drawn subsoil plow adjusted so that the point runs four or five inches below the surface. The plants are dropped at intervals along the soft track formed by the subsoiler and planting is accomplished by placing the fingers on the stolon piece and forcing it well below the surface. The soil is then thoroughly packed around the plant by hand.

A still more rapid method of vegetative propagation consists of opening shallow furrows with a horse-drawn row-marker, dropping stolon cuttings rather thickly in the furrows, and covering with a horse-drawn shovel cultivator.

An experimental plot was planted on February 29, 1940, by this method, with seeding at the rate of 1 bushel of cuttings per 400 feet of row. Cuttings were obtained from a 1939 planting by plowing out stolons with a one-horse mold-board plow which had a very sharp rolling coulter set to run almost as deep as the plow point. The old planting yielded cuttings at the rate of approximately 290 bushels per acre. An unusually good stand was obtained and growth was excellent. It appears, however, that seeding was unnecessarily heavy, and it is probable that 1 bushel of cuttings per 800 feet of row would provide an adequate stand.

This method of planting would seem to be much better adapted to large scale operations than propagation by shoots, because hand operations could be reduced to a minimum, and the work done chiefly by power equipment.

SEED PROPAGATION

Seed production by the cultivated goldenrod at Savannah has been very uncertain due to the presence of blossom blight (probably fusarium sp.). Some seasons this organism has attacked the flowers so severely that the seed crop has been almost a total failure, but even in seasons of light infestation, the seed has been very poor in viability. No tests conducted have ever indicated a germination percentage higher than 5%, and in most cases it has been much below this figure.

Experiments indicate that goldenrod seeds will germinate in a number of different soil mixtures, and in either pots or flats, provided they are not covered too deeply, and a constant supply of moisture is maintained.

A successful method of germinating goldenrod seed is to sow broadcast in a shallow wooden flat filled with a mixture composed of 50 per cent sand, 40 per cent composted soil, and 10 per cent peat moss, to which a small amount of steamed bonemeal has been added. The seeds are covered with a very thin layer of the above mixture which has been finely screened.

The flats are moistened from the bottom by immersing them in a shallow pan of water. If watered from the top the water should be broken up into an extremely fine spray and supplied with moderate pressure, to prevent washing the seeds out of the soil mixture.

If germination tests have shown that the seed is of low viability they may be sown very thickly. Excellent stands have been obtained in this manner from seed that germinated no better than 2 per cent in a preliminary test.

The flats may be placed either in greenhouse or slathouse, but the former is preferable as the growth rate of the seedlings is much more rapid when complete protection from low temperatures is provided. It has been found that early spring is the most advantageous time for setting out plants, and in order to have plants ready for the field March 1 it is necessary to sow seeds about January 1.

When the seedlings have 2 to 4 true leaves, they should be transplanted into another flat where they are spaced about 2 X 3 inches. This allows sufficient space for them to grow to a size suitable for transplanting to the field.

In transplanting the seedlings from the flat to the field, it is very desirable to handle them in such a way that a large ball of earth will adhere to the roots of each plant. High mortality has resulted when seedlings were set out without this ball of dirt.

Recent work with outdoor seed beds appears to indicate that goldenrod seed may be successfully germinated without greenhouse protection, but that growth is much slower.

One outdoor seed bed was planted in late January, and though germination was fairly good, the seedlings were not large enough to be transplanted to the field by April 1st. Greenhouse grown seedlings planted at the same time, were plenty large to transplant to the field March 15.

Seed planted in outdoor beds in June, have also shown fairly good germination and slow growth rate. However, summer plantings in the latitude of Savannah are not practical because high termperature and rapid drying characteristics of the topsoil make it extremely difficult and expensive to maintain desirable soil moisture conditions. Weed control is another difficult problem in summer plantings.

It has been definitely established that goldenrod is more or less heterozygous, and does not breed true to type when sexually propagated. For this reason, and also because it is much more expensive, seed propagation is definitely less desirable than vegetative propagation for any purpose except experimental breeding.

SPACING

Experiments were conducted in 1936 and 1937 in an effort to determine how goldenrod should be spaced in a field planting to produce the maximum yield of rubber per square foot.

Spacing investigations carried out by the Edison Botanic Research Corporation at Ft. Myers, Florida, indicated that optimum yields were obtained when the plants were set very close together, for example, 6 inches by 6 inches. The Ft. Myers experiments, however, were not carried out under conditions typical of an ordinary field planting, and it was thought desirable to obtain data on the relative yield of spacings which would be practical from a field culture standpoint.

- 1936 EXPERIMENT -

The experimental material consisted of sixteen blocks of S. leavenworthii, each 6 feet in width and 50 feet long. Eight of the blocks were control blocks in which the plants were spaced 12" X 8" or 12" X 16" depending on whether the block was adjacent to an 8" or a 16" spaced test block. The spacings used in the test blocks were 12" X 8", 12" X 16", 18" X 8", 18" X 16", 24" X 16", 24" x 8" (double row) and 24" X 16" (double row). The control blocks were

arranged alternately with the test blocks. An area of 6 feet by 25 feet, or 150 square feet, was harvested from each block.

Variance analysis of the data showed that there was no significant difference between the spacings in rubber per cent, yield of dry leaves per square foot, or in yield of rubber per square foot. No test block was significantly different from the adjacent control block in yield of rubber per square foot.

There was, however, a consistent advantage in favor of the 8" spacing regardless of distance between rows in both leaf yield and in yield of rubber per square foot, and even though it was not possible to demonstrate any statistically significant difference, due to the poor design of this experiment, it is entirely possible that there is a real advantage in favor of the 8" spacing.

In rubber per cent the plants spaced 16" apart in the row were consistently better than those spaced 8" apart in the row, regardless of row distance.

Inasmuch as the design of this experiment was not such as to permit adequate statistical analysis of the data, any inferences drawn, necessarily must be only tentative. However, the advantages of the 8" blocks over the 16" blocks in leaf yield and yield of rubber per square foot, regardless of distance between rows; and the advantages of the 16" blocks over the 8" blocks in rubber percent regardless of distance between rows, are too consistent to be ignored completely. (See Table I).

TABLE I

Rubber Per Cent, Dry Weight of Leaves per square foot and Grams of Rubber per Square foot of S. leavenworthii, 573-E in Eight differently spaced blocks harvested September 24, 1936

	12" X 8"	12" X 16"	18" X 8"	18" X 16"	24" X 8"	24" X 16"	24" X 8" Double Row	24" X 16" Double Row
Rubber %	3.26	3.53	3.31	3.66	3.19	3.52	3.19	3.35
Dry Wt. of Lvs. Per Sq. Ft. (in gms.)	23.44	22.68	29.48	24.19	26.46	23.44	24.95	22.11

	12" X 8"	12" X 16"	18" X 8"	18" X 16"	24" X 8"	24" X 16"	24" X 8" Double Row	24" X 16" Double Row
Rubber per sq. ft. (in gms.)	0.764	0.801	0.976	0.885	0.844	0.825	0.796	0.741

- 1937 EXPERIMENT -

Experience has shown that any distance between rows less than 24" is not practical for field plantings that are to be cultivated with horse drawn implements. For this reason, all row spacings below this figure were eliminated from consideration, and the 1937 experiments confined to a comparison between 24" and 30" row spacings, and comparisons between 8", 16" and 24" spacings in the row.

The first experiment was a simple comparison between 8" and 16" spacing in the row, all rows being 24" apart. There were ten 6-row blocks, each 48 feet in length. Five of the blocks had 8" spacing and were arranged alternately with the five 16" blocks. Two 48 square feet samples were taken from each block.

Variance analysis of the data showed a highly significant difference in favor of the 8" spacing in both yield of leaves per square foot and yield of rubber per square foot. There was no significant difference between the two spacings in rubber per cent. (See Table II).

In the second experiment, there were 24 randomized plots, and six different spacings. This provided 4 replications of each spacing. The spacings compared were 24" X 8", 24" X 16", 24" X 24", 30" X 8", 30" X 16" and 30" X 24".

Data obtained from this experiment is of doubtful value because of a severe infestation of blight which killed large number of plants in certain spots scattered through the planting. The death of these plants, of course, changed the planned spacing arrangements, and the only way any information at all could be obtained from the original yield data, was to assume proportionate yields for the missing plants, and make arbitrary corrections.

When the corrected data was analysed, it was found that yields of dry leaves per s uare foot and rubber per square foot, were in inverse proportion to spacing in row, regardless of distance between rows. In other words, the closer the spacing in the row, the greater the yield. Differences between 8" and 16" spacings were not significant, but both

were significantly better than the 24" spacing when the rows were 24" apart. Only the 8" spacing was better than the 24" when the rows were 30" apart.

TABLE II

Rubber per cent, Dry Weight of Leaves per Sample and Rubber per Square Foot of 8 inch and 16 inch spaced Blocks of S. leavenworthii, 573-C Harvested September 29, 1937.

	Rubber Per Cent		Dry Weight of Leaves per Sample (in oz.)		Rubber per Sq. Ft. (in gms.)	
	8 inch spacing	16 inch spacing	8 inch spacing	16 inch spacing	8 inch spacing	16 inch spacing
	4.46	4.91	23	18	0.606	0.525
	4.23	4.33	21	20	0.525	0.511
	4.69	4.65	23	21	0.637	0.577
	4.22	4.90	24	18	0.598	0.521
	4.53	4.33	21	16	0.562	0.409
	4.46	4.42	22	16	0.580	0.418
	5.67	4.92	18	18	0.603	0.523
	5.33	4.82	19	18	0.598	0.512
	4.87	5.17	18	13	0.518	0 397
	5.14	5.30	19	15	0.577	0.470
Mean-	4.76	4.78	20.8	17.3	0.580	0.486

Blocks having the rows 24" apart yielded slightly better than blocks having the rows 30" apart on the basis of leaves per square foot and rubber per square foot, but these differences were not significant.

There was no significant difference between any of the six spacings in rubber per cent. (See Table III).

The highly significant results of the first experiment left little doubt as to the superiority of the 8" spacing in the rows, over the 16" spacing. The results of the second experiment insofar as such data may be relied on, provide additional corroborative evidence.

In arriving at an optimum distance between rows, convenience of cultivation is the deciding factor, because there was no significant difference between the 24" and the 30" distance in either leaf or rubber yield, regardless of the space between plants in the row.

In view of the unreliability of some of the 1937 data, conclusions can only be tentative, but until additional evidence is available, the 30" by 8" spacing must be regarded as optimum.

TABLE III

Rubber Per Cent, Corrected Yield of Dry Leaves per Plot and Corrected Yield of Rubber per Plot, of differently spaced Plots of S. leavenworthii, 573-F harvested October 4, 1937

(Figures represent Mean of 4 Replications)

	24"X8" Spacing	24"x16" Spacing	24"x24" Spacing	30"x8" Spacing	30"x16" Spacing	30"x24" Spacing
Rubber Per Cent	2.94	3.00	3.02	3.02	2.95	3.24
Corrected Yield of Dry Leaves per Plot (in gms.)	1034.0	956.5	523.6	923.4	669.2	577.8
Corrected Yield of Rubber Per Plot (in gms.)	30.08	28.64	15.87	27.79	19.73	18.73

- 1938 EXPERIMENT -

The 1936 and 1937 experiments established rather definitely that 8 inch spacing of plants in the rows was optimum for goldenrod, but data on distance between rows was less conclusive. There were, however, definite indications that either a 24" or a 30" in distance between rows was most desirable in order to obtain maximum yield and still employ standard horse-drawn cultivating equipment.

The 1938 spacing experiment was, therefore, designed to afford a direct comparison between yield of plants spaced 24" x 8" and plants spaced 30" x 8".

The experimental material consisted of 3000 plants of S. leavenworthii, 573-C, arranged in eight 5-row blocks each 50 feet long. In four of the blocks the plants were spaced 24" x 8" and in the four alternate blocks, plants were spaced 30" x 8". Each block was divided into two 25 ft. plots. Samples taken from each plot for yield determination and rubber analysis consisted of an 8 foot section of the two inside rows.

Variance analysis of the data indicated that there was no significant

difference in yield of dry leaves per square foot, rubber per cent, or rubber per square foot, between the two spacings.

The mean yield of leaves per square foot, and rubber per square foot was slightly higher, and rubber per cent slightly lower in the 24" blocks, but, as stated above, none of these differences were significant.

Since yield differences between the two spacings are negligible, any choice must be dictated by convenience in operating farm implements, and from this standpoint the 30" distance between rows is much more desirable than 24".

TABLE IV

Comparison of 24"x8"x30"x8" spacings on the basis of dry leaf yield per square foot in grams, rubber per cent, and grams of rubber per square foot. Experiment #803 S. leavenworthii 573-C harvested September 16, 1938

(Figures represent mean of 8 replications)

	24"x8" Spacing	30"x8" Spacing	Value of F	F value necessary for 5% significance
Leaves per Sq.Ft. (Grams)	8.815	7.884	1.80	4.60
Rubber Per Cent	6.61	6.87	0.38	4.60
Rubber Per Sq. Ft. (Grams)	0.579	0.538	1.80	4.60

FERTILIZATION

Experiments were conducted in 1935 and 1936 for the purpose of determining whether or not the amount of rubber produced by a goldenrod plant may be increased by the use of commercial fertilizers. And since these experiments indicated that the production of rubber per plant was significantly increased by the use of commercial fertilizer formulas, the nutritional requirements of goldenrod were investigated more specifically in 1937 and 1938.

- 1935 Experiment -

The 1935 experiment consisted of 9 blocks of S. leavenworthii, each block being a different selection, or variety. Each block consisted of four 50-foot rows, 8 inches apart, plants spaced 8 inches apart in rows. Half of each block was fertilized with a commercial fertilizer (5%N - 7%P - 5%K) at the rate of 1,350 pounds per acre, and half of each block was left unfertilized for a control. The fertilizer was put on in a single application about one month after the plants were set out.

Since this experiment was also used to obtain data regarding optimum harvest time, samples were taken from both the fertilized and unfertilized sections of each block at seven different dates, starting August 2 and ending November 4. Samples were taken every two weeks during this period. A sample consisted of 8 plants, 2 plants from each of the 4 rows of the block.

The mean yield of leaves per plant of the fertilized sections of the 9 blocks was larger than the comparable yield of the unfertilized sections on every harvest date except August 2. The mean of all harvests of the fertilized series was 8.35 gm. per plant (dry wt.), while the comparable figure for the unfertilized series was 6.87 gm. This difference of 1.48 gm. of leaves per plant is highly significant.

Some selections appeared to respond more vigorously to the fertilizer application than others, but in every case the yield of leaves per plant (mean of 7 harvests) of the fertilized section was greater than the yield of the unfertilized section.

The rubber content (mean of 9 selections) of the samples taken from the unfertilized sections was larger than that of the samples from the fertilized sections on five of the seven harvest dates. On August 15 and September 16 the rubber content of the samples from the fertilized sections were higher.

The mean rubber content of all harvests of the fertilized series was 6.15%, while the comparable figure for the unfertilized series was 6.35%. This difference of 0.20% is not significant.

Seven of the nine selections showed a higher rubber content in the unfertilized section (mean of 7 harvests) than in the fertilized section. This fact, together with the tendency of the fertilized series to show lower rubber content, regardless of the date harvested, would seem to indicate that the application of fertilizer to goldenrod tends to reduce the percentage of rubber, even though no statistically significant difference can be demonstrated by this experiment.

The yield of rubber per plant (mean of 9 selections) of the fertilized

series was higher at every harvest, except one (August 2), than the yield of the unfertilized series. The mean yield of rubber (all harvests, 9 selections) of the fertilized series was 0.5046 gm. per plant, while that of the unfertilized series was 0.4288 gm. per plant. The difference of 0.0758 gm. per plant in favor of the fertilized series is very highly significant. There was only one selection out of the nine whose unfertilized section outyielded the fertilized section on the basis of rubber per plant (mean of 7 harvests).

The highly significant increase in leaf yield due to the use of fertilizer, may be considered to have more than counteracted the slight tendency of the fertilizer to decrease the rubber percentage, and the net result was a very highly significant increase in the yield of rubber per plant.

A more detailed comparison of the vegetative characters of the fertilized and control series indicated that some characters were definitely affected by the use of fertilizer while others apparently were influenced little, if any.

The production of stolons was greatly stimulated by the use of fertilizer as indicated by the fact that the mean number of stems per sample in the fertilized series (all harvests, 9 selections) was 17.63, while the corresponding mean for the unfertilized series was 14.82. The difference in favor of the fertilized plants was 2.81 stems per sample, a highly significant figure.

The greater number of stolons produced by the fertilized plants may be considered one of the chief factors contributing to the greater yield of leaves per plant of the fertilized series.

Leaf width was also very significantly increased by the use of fertilizer. Without exception the 9 selections showed a greater mean leaf width (mean of 4 harvests) in the fertilized series than in the unfertilized series. The mean leaf width of the fertilized plants was 11.86 mm and the mean width of the unfertilized was 10.68 mm. The difference of 1.18 mm. in favor of the fertilized series is very highly significant.

There was a slight, but not statistically significant, difference in height between the fertilized and unfertilized series. The mean height of the unfertilized plants was 147.2 cm. and the mean height of the fertilized plants was 143.2 cm. No reasonable explanation of the shorter stature of the fertilized plants is available.

The use of the fertilizer tended to increase the leaf length, though the difference between the means of the fertilized and unfertilized series is barely significant. The mean leaf length of the fertilized

series (mean of 4 harvests) was 89.04 mm, while the comparable figure for the unfertilized series was 84.86 mm. The difference of 4.18 mm. between means is barely significant.

The loss of lower leaves in the fertilized and unfertilized sections was compared by measuring the distance in cm. to the lowest green leaf and then computing the per cent of the stem on which the leaves were dead. This character is commonly termed per cent bare. It was quite obvious from an inspection of the data that there was no significant difference between the fertilized and unfertilized sections, so a variance analysis for this character was not made.

The most important effect of the fertilizer application was, of course, the highly significant increase in yield of leaves per plant. A plant, however, consists of all its stolon shoots, as well as the original main stem, so it is obvious that any treatment which stimulates stolon production will increase leaf yield. And since the data indicated that the use of fertilizer definitely increased the number of stolons, it may be concluded that the increase in yield was due chiefly to this factor.

The rubber per cent was not appreciably altered as a result of the use of fertilizer. With the rubber per cent practically unchanged and a greatly increased leaf yield, the yield of rubber per plant, of course, would be much greater in the fertilized series. It was found that the difference in this character in favor of the fertilized series was very highly significant.

The effect of fertilizer on certain vegetative characters which were studied, was variable. Leaf length was slightly increased by the additional plant food, and leaf width was increased to a highly significant extent. There was no significant difference in the height of the fertilized and unfertilized plants, and no difference in loss of lower leaves, (See Table I).

Allowing 26,460 plants per acre, the theoretical increase in the production of rubber per acre by using 1,350 lbs. of 5-7-5 fertilizer per acre would be 2,005.67 grams or 4.42 lbs.

- 1936 EXPERIMENT -

Results obtained in the 1936 fertilizer experiment were almost identical with the 1935 findings, although only a single selection of S. leavenworthii was used instead of 9 different selections. There were no replications in 1936 but nine sets of data were obtained by taking samples and plant measurements at intervals of two weeks during the period of July 15 - November 6.

The experimental material consisted of a single 4 row block of S. leavenworthii 573-M. The rows were 66 feet in length and 8 inches apart, and the plants were spaced 8 inches apart in the row.

TABLE I

Comparison of Fertilized and Unfertilized Sections of Experiment #502. Mean of 9 Selections, 7 Harvests *.

Character	Fertilized Section	Unfertilized Section	+ OR - Difference due to use of Fertilizer	Value of F	Significance
Yield of Leaves per Plant (Net dry wt.)	8.35 gm.	6.87 gm.	+ 1.48 gm.	57.99	Very highly sig.
Rubber %	6.15 %	6.35%	- 0.20%	3.48	Not significant
Rubber per Plant	0.5046 gm.	0.4288gm.	+ 0.0758 gm.	21.50	Very highly sig.
No. of Stems Per Sample (8 Plant Sample)	17.63	14.82	+ 2.81	25.24	Very highly sig.
Height	143.2 cm.	147.2 cm	- 4.0 cm.	0.70	Not sig.
Leaf Length	89.04 mm	84.86 mm	+ 4.18 mm.	5.58	Barely sig.
Leaf Width	11.86 mm.	10.68 mm.	+ 1.18 mm.	47.35	Very highly sig.

*Note: Figures for height, leaf length and leaf width represent mean of first 4 harvest dates as these measurements were discontinued during the latter part of the season.

A popular commercial formula (5.14% N - 8.75% P - 6.25% K) was broadcast in a single application at the rate of 1320 lbs. per acre. It was applied to half the block, about 3 weeks after planting, and the other was untreated.

Variance analysis of the data indicated that there was a very highly significant increase in the yield of leaves per plant and in the number of stems per sample where fertilizer was used. The yield of rubber per plant was also significantly increased by the use of fertilizer, but to a lesser degree than was found for the two characters previously referred to.

As in 1935, the mean height of the plants in the unfertilized section was greater than that of the fertilized plants, but the difference was not statistically significant.

In loss of lower leaves, there was no significant difference between the fertilized and unfertilized plants.

Leaf measurements were not taken in 1936, so the influence of fertilizer on the development of these organs could not be determined.

The remarkably close agreement between the 1935 and 1936 results corroborate the 1935 conclusions and they need not be repeated at this point in the discussion. (See Table II).

- 1937 EXPERIMENTS -

Since the effect of moderate applications of so-called "complete" fertilizers had been well established by the 1935 and 1936 experiments, it was not considered necessary to pursue this line of investigation further. It was, however, thought desirable to study the nutritional requirements of goldenrod more specifically, in order to determine, if possible, which element, or combination of elements was most essential for optimum plant development and rubber production.

TABLE II

Comparison of Fertilized and Unfertilized Sections of Experiment #602. S. leavenworthii, 573-M Mean of 9 Harvests.

Character	Fertilized Section	Unfertilized Section	+ OR - Difference due to use of Fertilizer	Value of F	Significance
Yield of Leaves per plant (Net dry wt.)	8.65 gm.	6.98 gm.	+ 1.67 gm.	26.45	Very highly sig.
Rubber %	4.98%	5.23%	- 0.25%	0.96	Not significant.
Rubber per Plant	0.442 gm.	0.372 gm.	+ 0.070 gm.	7.33	Significant
No. of Stems per Sample (8 plant sample)	21.11	16.67	+ 4.44	19.91	Very highly sig.
Height	167.89 gm.	173.00 cm.	- 5.11 cm.	3.54	Not sig.
% bare	15.97%	16.63%	- 0.66%	0.40	Not significant

To this end, two experiments were conducted in 1937, one a field experiment and one a pot experiment. The field experimental material consisted of 1,536 plants of S. leavenworthii 573-E, grouped into forty-eight 32 plant plots. Each plot consisted of 4 rows, 8 plants per row, rows 2 feet apart and plants spaced 8 inches apart in the row.

Eight different fertilizer mixtures were used and each mixture was applied to six plots. The plots chosen to receive a given mixture were selected by a process of randomization.

Three fertilizer ingredients were used in making up the mixtures, Nitrate of Soda, Superphosphate and Muriate of Potash. The eight different mixtures were made by combining single or double quantities of each ingredient with single or double quantities of each other ingredient.

A mixture having a single quantity of a given ingredient, say Nitrate of Soda, contained 75% as much Nitrogen as would have been derived from a 1,320 lb. per acre application of a 5-9-6 formula (1936 rate), while a mixture containing a double quantity of the ingredient in question would have 150% as much.

The relative amounts of the 3 elements in the mixtures are shown below. Exponents indicate single or double quantity of element.

Mixture No.	
1	- N^1 P^1 K^1
2	- N^2 P^1 K^1
3	- N^1 P^2 K^1
4	- N^2 P^2 K^1
5	- N^1 P^1 K^2
6	- N^2 P^1 K^2
7	- N^1 P^2 K^2
8	- N^2 P^2 K^2

The fertilizer was applied as a side dressing about 6 weeks after planting. The 2 outer rows of each plot and 2 plants on each end of each inside row were discarded at harvest time, and an 8 plant sample taken.

Variance analysis of the data indicated no significant difference in yield of leaves per plant, rubber per cent or yield of rubber per plant, between the means of any of the series, regardless of mixture used.

However, plots which received Mixtures, #6, #7 and #8 had a significantly larger number of stems per sample than plots receiving Mixtures #1 or #2. Mixtures #1 and #2 averaged $3\frac{1}{2}$ units of plant food each, while

Mixtures #6, #7 and #8 averaged 5-1/3 units each, and it would be expected that the higher analysis mixtures should stimulate stolon production to a greater extent. This result is in agreement with the 1935 and 1936 findings, as it was observed in both years that one of the principal effects of the fertilizer was to stimulate stolon production. In the 1937 experiment, however, the increase in number of stolons in the plots where the high analysis mixtures were used, was not sufficient to produce a yield of leaves per plant significantly higher than the yield of the low analysis plots.

Mixtures #6, #7 and #8 all contain a double quantity of Potash, and with the exception of #6, also have a double quantity of Phosphorous, while Mixtures #1 and #2 each have only a single quantity of these elements. This would seem to indicate that P and K are more essential to stolon production than N, though this point would have to be investigated further to justify any positive conclusions.

POT FERTILIZER

Material used in the Pot Fertilizer experiment consisted of 48 plants of S. leavenworthii 3s-82. Each plant was placed in a 6 inch clay pot, and half the number grown in the greenhouse, while the others were grown in the open. The culture medium (except Treatment #2) consisted of pure, thoroughly washed sand. Plants receiving Treatment #2 were potted in a soil mixture consisting of 50% sand, and 40% composted soil, 10% sedge muck, and a small quantity of bone meal.

There were six treatments used, and of the eight pots receiving a given treatment, 4 were in the greenhouse and 4 outside. A process of randomization was used in deciding which treatment each pot should receive.

Treatments were as follows:

Treatment
No.

1 - Sand (Unfertilized Control)
2 - Potting soil only. No Fertilizer.
3 - Sand - 3.32 gm. Nitrate of Soda per pot.
4 - Sand - 5.31 gm. Superphosphate per pot.
5 - Sand - 1.27 gm. Muriate of Potash per pot.
6 - Sand - 11.34 gm. Vigoro per pot.

These quantities were not given at a single application, but divided in thirds and put on at monthly intervals beginning about 10 days after planting. The plants were harvested and analyzed individually. Plant measurements were taken just prior to harvest.

Variance analysis of the data on leaf yield indicated that treatments #2, #3, and #6 were significantly better than the untreated control, with #2 significantly better than #6, and #6 significantly better than #3.

When the leaf yield data on the greenhouse grown plants were analyzed separately from the data obtained from the plants grown in the open, it was found that, while the relative yield of the various treatments was similar, the mean yield of greenhouse grown plants was more than double that of the outside plants.

On the basis of rubber percent, Treatment #2, #3 and #6 were all significantly higher than Treatments #4 and #5 and the untreated control (#1). Treatments #4 and #5 were not significantly different from each other, and were not significantly better than the control.

Without exception, greenhouse grown plants had a higher rubber content than plants grown outside, providing they received the same fertilizer treatment. The relative rubber content of the various treatments among the greenhouse plants was the same as described above, but in the outside group, although Treatments #2, #3 and #6 were higher in rubber content, #6 (the poorest of the three) was not significantly higher than #4. Number 4 was significantly higher than #5 and #1, the two latter not differing significantly from each other.

In rubber per plant, Treatments #2 and #6 were outstanding, both being significantly better than any of the other 4 treatments. Number 2, however, was significantly better than #6. Neither Treatment #3, #4 or #5 was significantly better than the control (#1), although Treatment #3 was much higher than #4 or #5.

By analysing the greenhouse and outside data separately it is possible to demonstrate the significance of the greatly increased yield of Treatment #3 over #1, #4 and #5. The relative yield of the other treatments was found to be practically the same when the data were grouped as when treated as a whole (see preceding paragraph). The mean yield of rubber per plant of greenhouse grown plants was more than double that of plants grown outside.

Plants receiving Treatment #2 were significantly taller than those receiving any of the other treatments. Treatment #6 ranked second in height and was significantly taller than #3, the third ranking treatment. Treatments #4 and #5 were not significantly taller than the control (#1), and both were significantly shorter in stature than any of the three best treatments (#2, #6 and #3).

When the data on the greenhouse plants were studied separately from those of the outside plants, it was found that there was no significant difference among the three top ranking treatments in the greenhouse. All three were significantly taller than Treatment #1, #4,

and #5, the three latter not differing significantly among themselves.

The same relationship held true for the plants grown in the open, except Treatment #2 showed a significant advantage over #3 and #6.

There was no significant difference between Treatments #2, #3 and #6 in loss of lower leaves, and these three treatments were all significantly better in this respect than #1, #4 or #5. Numbers 4 and 5 were not significantly better than the control (#1).

Plants grown outside lost nearly twice as many lower leaves as plants grown in the greenhouse. The same relative leaf loss among the various treatments as discussed above, was found in the outside plants, except that Treatment #4 was significantly better than either the control (#1) or Treatment #5.

Among the greenhouse grown plants, only treatment #2 had a significantly lower loss of leaves than the control (#1). Treatment #3 and #6 were much better than #4 or #5 but the differences are not statistically significant.

TABLE III

Experiment # 711
Comparison of Six Treatments on the Basis of Five Different Characters
(Figures represent Mean of 8 Replications)

Treatment #1 Untreated Control	Treatment #2 Potting Soil	Treatment #3 Nitrate of Soda	Treatment #4 Superphosphate	Treatment #5 Muriate of Potash	Treatment #6 Vigoro
LEAVES PER PLANT					
0.24 gm	7.29gm.	1.32gm	0.29gm	0.36gm	3.04gm
RUBBER PER CENT					
4.00%	6.90%	6.46%	4.71%	4.23%	6.50%
RUBBER PER PLANT					
0.010gm	0.514gm	0.089gm	0.014gm	0.016gm	0.216gm
HEIGHT					
37.75cm	153.12cm	111.75cm	39.62cm	38.62cm	131.25cm
PER CENT BARE					
53.88%	26.25%	30.25%	45.38%	53.25%	29.25%

TABLE IV

EXPERIMENT #711

Comparison of Six Treatments on the Basis of Five Different Characters, With Data on Greenhouse Series Separate from Outside Grown Series.

(Figures represent Mean of 4 Replications)

Character	Series	Treatment #1 Untreated Control	Treatment #2 Potting Soil	Treatment #3 Nitrate of Soda	Treatment #4 Superphosphate	Treatment #5 Muriate of Potash	Treatment #6 Vigoro
LEAVES PER PLANT	Greenhouse	0.30 gm.	9.32 gm.	1.90 gm.	0.35 gm.	0.52 gm.	4.78gm.
	Outside	0.18 gm.	5.25 gm.	0.75 gm.	0.22 gm.	0.20 gm.	1.30 gm.
RUBBER PER CENT	Greenhouse	4.49%	7.55%	7.02%	4.70%	4.76%	7.57%
	Outside	3.51%	6.24%	5.91%	4.72%	3.70%	5.43%
RUBBER PER PLANT	Greenhouse	0.014gm.	0.700gm.	0.134gm.	0.017gm.	0.025gm.	0.361gm.
	Outside	0.006gm.	0.327gm.	0.044gm.	0.010 gm.	0.007gm.	0.071gm.
HEIGHT	Greenhouse	44.25 cm.	146.25cm.	127.50cm.	35.75 cm.	41.50cm.	155.00cm.
	Outside	31.25cm.	160.00 cm.	96.00cm.	43.50cm.	35.75cm.	107.50cm.
PER CENT BARE	Greenhouse	37.75%	17.25%	19.25%	35.75%	37.00%	18.25%
	Outside	70.00%	35.25%	41.25%	55.00%	69.50%	40.25%

The most striking result of the experiment was the obvious superiority of the plants grown in potting soil over the plants grown in sand, regardless of kind or amount of fertilizer applied to the latter. It was beyond the scope of this investigation to determine whether this superiority was due to the undected presence in the potting soil of some essential minor element, or whether the greater organic content of the potting soil tended to increase the yield and rubber content. The advantage of the plants grown in potting soil over the plants receiving other treatments was much greater when the plants were grown in the open than when grown in the greenhouse. In fact, among the greenhouse grown series, plants receiving Treatments #3 and #6 were approximately equal to the plants grown in potting soil, in rubber content, height, and per cent bare, though significantly inferior to the latter in leaf yield and rubber per plant.

The plants which were grown in the open, probably lost a greater amount of the inorganic plant foor elements by leaching, than those in the greenhouse. And if the organic elements contained in the potting soil are less subject to loss by leaching, this might partially account for the results mentioned in the preceding paragraph.

In comparing Treatments #3, #4 and #5 (the single ingredient treatments), it is notable that plants receiving Treatment #3 (Nitrate of Soda) were significantly better than either of the other two in all characters studied. Treatment #3 was significantly better than the control (1) in leaf yield, rubber per cent, height and per cent bare; but not in rubber per plant.

The plants receiving Treatments #4 (Superphosphate) and #5 (Muriate of Potash) were very poor and stunted. Neither was significantly better than the untreated control.

Of the three single ingredient treatments, Nitrate of Soda was the only one which produced anywhere near normal growth and rubber content. However, we have no information as to whether the better showing of Nitrate of Soda was because Nitrogen is more essential than P or K for normal goldenrod development, or whether some very essential minor element, present as an impurity in the Nitrate, was lacking in the other salts.

Summing up the results of the pot experiment, it may be said that the only plants which attained approximately normal development were those grown in the soil mixture containing a large percentage of organic matter, and those grown in sand and fertilized with Vigoro. The plants grown in sand and fertilized with single ingredients (either Nitrate of Soda, Superphosphate and Muriate of Potash) did not make normal growth, though the plants which received Nitrate of Soda were significantly better than those receiving Superphosphate or Muriate of Potash. The two latter series were not significantly better than plants grown in unfertilized sand. Plants grown in the greenhouse were definitely superior in leaf yield, rubber per cent, rubber per plant and height, to plants grown in the open, and the loss of lower leaves was significantly less.

- 1938 EXPERIMENT -

In 1938 a field experiment was conducted for the purpose of comparing the effect of certain fertilizer treatments on goldenrod leaf yield and rubber content. Among the treatments were commercial fertilizers applied at several different rates, commercial fertilizers supplemented with Nitrate of Soda side dressing, Nitrate of Soda alone, and organic fertilizer without mineral supplements.

The experimental material consisted of 4,320 plants of S. leavenworthii, 3 S - 82, grouped into sixty 72 plant plots. Each plot consisted of 4 rows, 18 plants per row. Plants were spaced 8 inches apart in the row, and rows were 30 inches apart.

Nine different fertilizer treatments were used, a given treatment being applied to a series of 6 plot chosen by a process of randomization. There was also a series of 6 untreated control plots at randomized locations throughout the experiment.

Each plot was sampled for yield and rubber determination, by taking 12 entire plants, 6 from each of the two inside rows.

All treatments were applied as a side dressing and thoroughly worked into the soil, approximately a month after the plants were set out. (Part of treatments #4 and #8 were applied July 1, when the plants were about 3-1/2 months old).

Treatments and rates of application were as follows:

Treatment #1 - Composted Soil - 5 Tons Per Acre.

This composted soil consisted of vegetable matter such as Plant Tops, Weeds, Grass Trimmings, Etc., placed with alternate layers of soil in compost piles and allowed to decompose for several years. No animal manures or chemicals added.

Treatment #2 - Sheep Manure - 4600 lbs. per Acre.

Dried Commercial Product Analyzing 2%n-1%P-2%K.

Treatment #3 - Nitrate of Soda - 16%N - 300 lbs. per Acre.

Treatment #4 - Nitrate of Soda - 16% - 300 lbs. per Acre in two applications. The Amount was divided and 150 lbs. per acre applied when the plants were one month old, and the remainder applied when the plants were about 3½ months old.

Treatment #5 - Commercial Mixture - 5.14%N-8.75%P-6.25%K 500 lbs. per Acre.

Nitrogen, 40% from organic source, 60% from inorganic sources, derived from Sulfate of Ammonia, Nitrate of Soda, Castor Bean Meal, Fish Scrap, Peruvian Guano, and Tankage.

Potash derived from Muriate of Potash.

Treatment #6 - Same Formula as #5 - 1000 lbs. per Acre.

Treatment #7 - Same Formula as #5 - 1500 lbs. per Acre.

Treatment #8 - Same Formula as #5 - 500 lbs. per Acre plus 200 lbs. per Acre Nitrate of Soda applied when the plants were about 3½ months old.

Treatment #9 - Vigoro - 4%N-12%P-4%K - 1000 lbs. per Acre.

Vigoro is a commercial mixture which contains a number of so-called minor elements such as Zinc, Boron, Manganese, Etc., in addition to the usual N, P & K.

Table V shows comparative costs per acre of the 9 treatments.

TABLE V

Comparative Material Costs of the Treatments Used in Experiment #804

Treatment No.	Description and Rate of Application	Cost per Ton	Cost per Acre
1	Composted Soil 5 tons per acre	$ 1.50	$ 7.50
2	Sheep Manure, 4600 lbs. per Acre	78.00	179.40
3	Nitrate of Soda, 300 lbs. per Acre	32.00	4.80
4	Nitrate of Soda, 300 lbs. per Acre	32.00	4.80
5	Commercial Mixture, 500 lbs. per Acre	26.00	6.50
6	Commercial Mixture, 1000 lbs. per Acre	26.00	13.00
7	Commercial Mixture, 1500 lbs. per Acre	26.00	19.50
8	500 lbs. Commercial Mixture plus 200 lbs. Nitrate of Soda		9.70
9	Vigoro - 1000 lbs. per acre	50.00	25.00

*Note: The cost of the Composted soil is an estimate, because it is very difficult to keep accurate record of the cost of preparing material of this type.

Variance analysis of the data indicated that some of the treatments were responsible for significant increases in yield of leaves and yield of rubber per plant, though in general the application of fertilizer tended to decrease the per cent of rubber in the leaves.

The effect of the fertilizer treatments on leaf yield, rubber per cent, and rubber per plant are considered in detail below.

Only those plants which received Treatments #6, #7 and #9 were significantly higher in leaf yield than the untreated control plants, although Treatment #2 also produced a large increase which lacked very little of being significant.

Nitrate of Soda alone, even when applied at the fairly heavy rate of 300 lbs. per acre, did not produce a significant increase in leaf yield. It was apparently more effective to put on the 300 lbs. of Nitrate of Soda at a single application early in the season, than to divide it into two applications of 150 lbs. each.

The 5-9-6 Commercial fertilizer mixture applied at the rate of 500 lbs. per acre, did not increase leaf yield significantly, either when used alone, or supplemented with a mid-season side dressing of 200 lbs. of Nitrate of Soda.

Of the two organic treatments tried, Sheep Manure was much more effective than composted soil, even though a very much heavier application of the latter was used. The Sheep Manure caused increases in leaf yield almost as great as the increase brought about by the use of relatively heavy applications of commercial mixtures, despite the fact that the concentration of N, P and K in the manure was very low.

From the standpoint of material expense, the Nitrate of Soda treatments were the cheapest and the Sheep Manure the most costly. However, cost studies on these two treatments and for treatments #1, #5, and #8 are of little value because none produced a significant increase in leaf yield.

Of the 3 treatments which produced significant increase in leaf yield, Treatment #6 was lowest in total cost of ingredients per acre, and lowest in cost per unit of yield increase.

Treatments #7 and #9 produced slightly larger increases in leaf yield than did #6, but the differences were not significant, and the treatments were considerably more expensive. Treatment #7 (1500 lbs. of 5-9-6) outyielded #6, but the difference was not significant. Treatment #9 (1000 lbs. of Vigoro) was more effective in increasing yield than treatment #7, possibly due to the presence in Vigoro of certain minor elements that ordinarily fertilizers do not contain, but the cost per unit of increase was considerably higher.

It would appear then, that from the standpoint of leaf yield, the 1000 lbs. per acre application of 5-9-6 was more efficient than any of the other treatments tried. Applications of commercial fertilizers at rates in excess of 1000 lbs. per acre are apparently not justified, because the yield increases obtained were not significantly larger than those produced by the 1000 lb. application and the cost was 50% greater. Expensive fertilizers, such as Vigoro, which contain minor plant food elements, did not increase leaf yield significantly over equivalent applications of ordinary commercial fertilizer.

The effectiveness of Sheep Manure in increasing yields confirms the

results of previous experiments which had indicated the importance of abundant organic matter for optimum growth of goldenrod.

TABLE VI

Comparison of Yield in Grams of Dry Leaves per Plant of Plants which received nine different Fertilizer Treatments with yield of untreated control plants in Experiment #804. S. leavenworthii 35-82.

Treatment No.	Mean Yield (6 Replications)	Increase* over Control	
9	17.20 grams	5.47 grams	Increase statis. significant
7	17.00	5.27	Increase statis. significant
6	15.87	4.14	Increase statis. significant
2	15.57	3.84	Increase not significant
8	15.27	3.54	Increase not significant
1	13.38	1.65	Increase not significant
5	13.13	1.40	Increase not significant
3	12.20	0.47	Increase not significant
4	10.78	- 0.95	Decrease not significant
Control	11.73		

Difference between Means necessary for significance: 5%-3.91; 1%-5.22

Yield necessary to be Sig. larger than Control - 15.64

*Note: This was a decrease instead of an increase in the case of Treatment #4.

In considering the effect of the different fertilizers on the rubber content of goldenrod, it is usually recognized that any treatment which increases the vegetative vigor of the plant tends to lower the percentage of rubber. The results of this experiment contribute additional evidence along this line, because it was found that plants which received the treatments that produced the best leaf yields, generally had a lower rubber content than the untreated control plants.

Treatments #6, #7, and #9 were the only ones which had a significantly higher leaf yield than the untreated control, and each of these was found to have a significantly lower rubber content than the control.

Conversely, Treatments #1, #3, #4 and #5, which were poorest in leaf yield, were found to be not significantly lower in rubber content

than the control. The two poorest of this low leaf yielding group were the highest in rubber per cent, actually exceeding the control in this character, though the difference was not statistically significant.

The mean rubber content of the high leaf yielding group (Treatments #6, #7, #9) was 5.85% while the mean rubber content of the low leaf yielding group (Treatments #1, #3, #4, #5) was 7.08%.

TABLE VII

Comparison of Rubber Per Cent of Dry Leaves of Plants which received Nine Different Fertilizer Treatments, with Unfertilized control plants in Experiment #804. S. leavenworthii 3s-82.

Treatment No.	Mean RBR% (6 Replic.)	+ Or - Diff. from Control	Significance
4	7.33	+ 0.20	Not sig. diff. from control.
3	7.32	+ 0.19	Not sig. diff. from control.
1	7.09	- 0.04	Not sig. diff. from control.
5	6.56	- 0.57	Not sig. diff. from control.
2	6.22	- 0.91	Significant lower than control.
8	6.11	- 1.02	Significant lower than control.
9	6.05	- 1.08	Significant lower than control.
7	5.79	- 1.34	Significant lower than control.
6	5.72	- 1.41	Significant lower then control.
Control	7.13		

Difference between Means necessary for significance - 0.76

Only one of the fertilizer treatments caused a significant increase in the mean yield of rubber per plant over the mean yield of the untreated control plots. This was Treatment #9, an application of Vigoro at the rate of 1000 lbs. per acre.

Other treatments which produced significant increases in leaf yield, at the same time caused a decrease in rubber per cent, hence, the net yield of rubber per plant was not significantly increased.

However the mean yield of rubber per plant of the high leaf yielding group (Treatment #6, #7, #9) was considerably higher than that of the high rubber content group (Treatments #1, #3, #4, and #5), the means being respectively 0.960 gm. per plant and 0.862 per plant.

TABLE VIII

Comparison of Yield of Rubber in Grams per Plant of Plants receiving Nine Different Fertilizer Treatments, with Unfertilized Controls in Experiment #804. S. leavenworthii 3s-82.

Treatment No.	Mean RBR Per Pl.(6 Replic.)	+ Or - Diff. From Control	Significance
9	1.012	+ .174	Significantly larger than control
7	.974	+ .136	Not Sig. different from control.
2	.964	+ .126	Not Sig. different from control.
1	.936	+ .098	Not Sig. Different from control.
8	.914	+ .076	Not Sig. different from control.
6	.893	+ .055	Not sig. different from control.
3	.874	+ .036	Not sig. different from control.
5	.858	+ .020	Not sig. different from control.
4	.778	- .060	Not sig. different from control.
Control	.838		

Difference between Means Necessary for Significance - .173.

Therefore, it may be said in conclusion that the use of any kind of fertilizer on goldenrod is not justified from an economic standpoint. For example, the use of 1000 lbs. of Vigoro (best of the treatments tried) increased the theoretical yield of rubber per acre by approximately 9.5 lbs. at 20¢ per lb., this rubber would be worth $1.90 while 1000 lbs. of Vigoro costs approximately $25.00.

CULTIVATION

The Savannah goldenrod investigation work has not included controlled experiments to compare different methods of cultivation. However, various standard hand and horse-drawn cultivating tools have been employed for stirring the soil and controlling weeds.

Hand operated wheel hoes with shovels, scuffle hoe attachments or Norcross attachments, have proved to be very effective in cultivating closely spaced plantings. In plantings where the rows are 30 inches or more apart, horse-drawn equipment has proved more efficient, with small, spike-tooth cultivators being used early in the season when the plants are small, and standard shovel cultivators being used later. Sweeps and other ridge or bed forming implements have been avoided because it is believed that piling soil up around the plant tends to inhibit stolon growth. Therefore, all cultivation has been carried

out in such a way as to keep the ground level. Hand hoeing has been depended on to control weeds in the row that could not be reached by the cultivator.

In a climate such as that which prevails at Savannah, with a normal annual rainfall of approximately 50 inches, weed growth is very rapid during the summer and cultivation must be frequent. A thorough working of the alleys between rows every two or three weeks supplemented with hand hoeing of the rows at somewhat longer intervals has proved effective in keeping goldenrod in thrifty condition under ordinary circumstances. It is occasionally necessary to cultivate oftener during periods of excessive precipitation.

The above statements apply only during the first growing season after the plants are set out. If a plot is to be carried more than one year without replanting, no cultivation whatever is required during the second and succeeding seasons. This is because stolon growth is so vigorous that the alleys between rows are completely filled with new shoots, and weed growth is effectively choked out. (This subject is treated more fully under the heading "Management and yield of Perennial Plantings".)

DATE OF HARVEST

Experiments were conducted in 1935, 1936 and 1937 for the purpose of determining the most advantageous time to harvest goldenrod. Work done by H. G. Ukkelberg for the Edison Botanic Research Corporation, at Fort Myers, Florida, indicated that the best rubber yields were obtained after the plants had approached, or attained, sexual maturity, and that the rubber content was very low when the plants were immature.

There were no data available, however, on the behavior of goldenrod in the vicinity of Savannah, and it was thought desirable to investigate the relationships existing between rubber content and plant maturity. Also the relationships between sexual maturity and such other characters as leaf yield, stolon production, height, loss of lower leaves, etc.

- 1935 EXPERIMENT -

Nine selections of S. leavenworthii were used in the 1935 experiment. There was one four-row 50 foot block of each selection. The rows were 8 inches apart in the block and plants spaced 8 inches apart in the row. An 8 plant bulk sample, consisting of 2 plants from each of the four rows, was taken from each block, every two weeks during the period August 2 to November 4, inclusive. Plant measurements

were made immediately preceding each harvest.

The mean rubber content of the 9 selections was lowest on August 2, highest on August 15, and next highest on October 15. There was no significant difference between the August 15, August 31, October 15, and November 4 means, and all were significantly higher than the August 2 mean. The September 16 mean was low but not significantly lower than any of the latter group except August 15. The September 16 mean was significantly higher than that of August 2 (See Table 1).

The mean yield of leaves per plant of the 9 selections was significantly lower on August 2 than at any other time during the remainder of the harvest period. There was no significant difference in the mean leaf yield on any of the last six harvest dates.

In rubber per plant the mean yield on August 2 was also significantly lower than at any other date on which samples were taken. The relative yield of rubber per plant on the last six harvest dates was, however, somewhat different than that found for leaf yield, since August 31 and October 15 were both significantly higher than September 16.

The mean number of stems per sample was largest on November 4, but not significantly larger than the mean of any other dates except August 2 and August 15. The October 1 and October 15 means were also significantly larger than the August 2 mean. The larger number of stems per sample found during the latter part of the growing season is in agreement with other observations which have indicated that goldenrod tends to produce more stolons as it approaches sexual maturity. Few stolons are produced during the earlier stages of the growing period.

There was a significant and fairly consistent increase in height during the period August 2 - November 4. The greatest increase took place between August 2 and August 15, and an almost equal amount of stem elongation took place between August 15 and August 31. The height remained practically constant from August 31, to October 1, but a significant increase occurred between October 1 and October 15. There was a slight increase between October 15 and November 4, but it was not significant.

There was a gradual, and consistently increasing loss of lower leaves during the period, August 15 - November 4. There was no appreciable leaf loss before August 15. The mean per cent bare on November 4 was more than twice as great as it was on August 15, this difference being highly significant. The most rapid loss of lower leaves occurred between October 15 and November 4, although a significant loss also took place during the two weeks between August 31 and September 16.

In evaluating the results of this experiment, the two very definite periods of maximum rubber per cent are worthy of note. Instead of a gradual increase or decrease in rubber per cent, a very high per cent was found early in the season (August 15), followed by a period of comparatively low percentages from August 31 to October 1, and then a sharp increase on October 15, at which time the mean rubber per cent was not significantly lower than it had been on August 15. After October 15 there was another slight decrease, but the November 4 mean was not significantly lower than the Octob r 15 peak.

In leaf yield and yield of rubber per plant, the findings were similar to those discussed in the last paragraph, except that the early season peaks were attained on August 31 instead of August 15. The later peak occurred on the same date as for rubber per cent (October 15).

TABLE I

Mean Rubber Per cent, Rubber per Plant, Dry Weight of Leaves per Plant, Number of Stems per 8 Plant Sample, Height, and Per cent Bare of 9 selections of S. leavenworthii at Fortnightly intervals between August 2 * and November 4, 1935.

	Aug. 2	Aug. 15	Aug. 31	Sept. 16	Oct. 1	Oct. 15	Nov. 4
Rubber%	5.23	6.56	6.33	6.04	6.19	6.43	6.28
Rubber per Plant (in gms)	0.308	0.520	0.584	0.476	0.501	0.589	0.569
Dry Wt. of Leaves Per Plant (in gms.)	5.90	7.99	9.37	8.07	8.40	9.46	9.29
No. of stems per 8 Plant Sample	15.44	16.11	17.44	16.89	18.78	18.78	20.00
Height (in cm.)	118.22	135.89	148.89	146.78	145.33	152.22	155.00
Per Cent Bare	0	7.04	7.22	9.30	10.49	11.48	15.64

*Note: There was no appreciable loss of lower leaves before August 15.

There was a gradual and more or less consistent increase in height, percent bare and number of stems per sample, between August 2 and November 4.

- 1936 Experiment -

The experimental material consisted of a single 4-row block of S. leavenworthii, 573-M. The rows were 66 feet in length, and 8 inches apart and the plants were spaced 8 inches apart in the row. Eight plant bulk samples consisting of 2 plants from each of the four rows of the block were taken at fortnightly intervals during the period July 15 - November 6, 1936.

Since there were no replications the data were not analysed by the variance method and no levels of significance could be determined.

Nevertheless the data may be of some value in connection with the 1935 and 1937 findings.

There is a definite similarity between the seasonal trends in rubber percent, leaf yield and rubber per plant in both 1935 and 1936. In 1936 the early season peak for all three characters occurred on August 27 and the later peak on October 9 in rubber per plant and leaf yield, and on October 23 in rubber percent. The period of comparatively low yields between peaks was not so pronounced as in 1935.

Height increased rather rapidly between July 15 and August 27, but from August 27 to the end of the harvesting period, the stature of the plants remained practically constant.

Percent bare increased more or less consistently up to September 28, but there was apparently no further loss of lower leaves after that date.

There was no well defined seasonal trend in number of stems per sample, with the possible exception of a slight tendency for the counts to be smaller on the first three harvest dates. (See Table II).

- 1937 Experiment -

The 1937 experimental material consisted of sixty 8-plant plots of S. leavenworthii, 573-E. The plots were grouped into six blocks of ten plots each, and one plot was harvested from each block on each harvest date. In this manner a series of six samples was obtained every 14 days. The plots taken at any given harvest were chosed by a process of randomization.

The mean rubber per cent on October 11 was significantly higher than the mean found on any other harvest date during the period covered by this experiment (Aug. 2 - Nov. 22). There was some evidence of an early season peak followed by a comparatively short period of lower percentages, similar to the findings of 1935 and 1936, but this tendency was less pronounced in 1937. The August 2 mean, however, was significantly higher than the mean on either of the next two harvest dates (August 16 and August 31), and while the August 2 mean was not nearly as high as that of October 11, it tends to furnish additional evidence in support of a conclusion that high rubber content may be obtained by harvesting in August, as well as later in the season when the plants are mature.

Rubber content fell off rather sharply after October 11, and the means found on the three succeeding harvests were all significantly lower.

Maximum leaf yields were obtained at the three harvests roughly corresponding to the month of September (August 31, September 13 and September 27). Yields were significantly lower prior to this period, and there was a slight decline at the next two harvests (October 11 and October 25) following this optimum period. Yields on November 8 and November 22 were significantly lower than any obtained during the optimum period.

Mean yield of rubber per plant was lowest on August 2, and increased consistently at each succeeding harvest until the maximum was reached on September 27. The mean at the next subsequent harvest date (October 11) was lower than that of September 27, but not significantly so.

TABLE II

Rubber Per Cent, Rubber Per Plant, Dry Weight of leaves per Plant, Number of Stems per 8 Plant Sample, Height and Per Cent Bare of S. leavenworthii, 573-M at Fortnightly intervals between July 15 and November 6, 1936.

	July 15	July 30	Aug. 13	Aug. 27	Sept. 10	Sept. 28	Oct. 9	Oct. 23	Nov. 6
Rubber %	3.49	3.95	3.68	5.33	4.18	5.33	6.14	6.61	6.10
Rubber Per Plant (In gms.)	0.215	0.273	0.302	0.533	0.334	0.549	0.694	0.529	0.549
Dry Weight of Lvs. per Plant (In gms.)	6.2	6.9	8.2	10.0	8.0	10.3	11.3	8.0	9.0

Table II cont'd.

	July 15	July 30	Aug. 13	Aug. 27	Sept. 10	Sept. 28	Oct. 9	Oct. 23	Nov. 6
No. of Stems per 8 Plant Sample	17	15	17	26	21	24	28	18	24
Height (in cm.)	127	132	164	184	175	186	187	175	181
Per cent Bare	4.0	9.2	10.1	14.1	12.0	25.3	23.0	23.0	23.0

Means on October 25, November 8 and November 22 were significantly lower than the optimum yields of September 27 and October 11.

One possible explanation of the bimodal rubber content curve, which was most pronounced in 1935 and 1936, and slightly less evident in 1937, is the fact that the plants harvested during August have not yet lost many lower leaves. It has been shown in other experiments (Leaf Maturity), that the older leaves near the base of the plant contain a higher percentage of rubber than the leaves higher up the stem. The rubber percent is quite low in the upper stem leaves in August, but increases considerably as the plant approaches maturity. The high yielding lower leaves, have been lost by the latter part of the season, but apparently the upper stem leaves have increased in rubber content enough to show a high average percent at the moderately late harvests. The relatively poor rubber yields of the very late harvests is probably due mainly to more severe leaf loss, which, of course, becomes progressively worse as the season advances. A measure of late season leaf loss is provided by the data on weight of leaves per plant. These figures show a steady decline from one harvest to the next after September 27.

With leaf yield at the maximum all through September, and rubber percent almost maximum on September 27, it is obvious that the highest yield of rubber per plant would be obtained on that date. Rubber per plant was not significantly lower on the next succeeding harvest date (October 11), because although the leaf yield was less, the rubber percentage had increased almost enough to balance the lower leaf yield. (See Table III).

It may be concluded that the optimum period for harvesting goldenrod, under the seasonal conditions prevailing in 1937, was late September or early October.

Summing up the results of three years work on this phase of goldenrod investigation, it appears that early October is the most desirable harvesting period, though there is also a period in August when rubber production is comparatively high. In 1935 and 1936, but not in 1937, the yields of rubber per plant during September, and especially the first part of the month, were comparatively low.

TABLE III

Rubber Per Cent, Dry Weight of Leaves per Plant and Rubber per Plant of S. leavenworthii, 573-E at fourteen day intervals between Aug. 2 and November 22, 1937.
(Figures represent mean of six plots harvested on date shown.)

	Aug. 2	Aug. 16	Aug. 31	Sept. 13	Sept. 27	Oct. 11	Oct. 25	Nov. 8	Nov. 22
Rubber per cent	2.28	2.13	1.98	2.39	2.60	2.82	2.40	2.32	2.59
Dry Wt. of Lvs. per Plant (in gms)	17.57	20.27	29.52	28.10	29.28	26.75	25.68	23.10	22.97
Rubber per Plant (in gms)	0.398	0.431	0.586	0.668	0.760	0.750	0.611	0.484	0.592

The possible effect on rubber content of the time of day at which leaves are taken, has also been investigated. Leaves of comparable age were harvested from a group of plants at 6:00 AM 12 Noon, and 6:00 PM but no significant differences could be found.

MANAGEMENT & YIELD OF PERENNIAL PLANTINGS

The standard practice in managing the field plantings of goldenrod at the Savannah station has been to replant each spring. In other words, the goldenrod plant has been grown as an annual rather than a perennial. It was well known, however, that once established, a planting would maintain itself indefinitely, but very little was known about how second year and later yields compared with first year yields, and there was no information available on thinning, weed control, fertilization, etc.

Experiments were conducted in 1936 and 1937 to compare several different methods of managing plantings that are to be left from year to year as perennials.

- 1936 EXPERIMENT -

The experimental material in 1936 consisted of an almost solid stand of S. leavenworthii 42 ft. x 48 ft. in size, which had been planted in March 1935. In March 1936 the area was thoroughly cut up by

running a disc harrow both lengthwise of the original rows and across them. Commercial fertilizer (5%N - 9%P - 6% K) was then applied broadcast at the rate of approximately 600 lbs. per acre. The area was divided into four blocks, with one of the four blocks left as an untreated control. The other three blocks were thinned in various ways. All the thinning, however, was done with a hoe and no provision was made for cultivation with horse-drawn implements.

The methods tried here must be considered ineffective, because the planting soon became severely overrun with weeds and the surviving goldenrod plants were so poor and stunted that they were not worth harvesting.

It was observed that the preliminary disking killed large numbers of goldenrod plants and it is very probable that the planting was thinned too much by this operation. This, together with the fact that effective cultivation was impossible, placed the goldenrod under a serious handicap in competition with weeds, and it must be concluded that these methods proved wholly unsatisfactory for handling perennial goldenrod plantings.

- 1937 EXPERIMENT -

A block of S. leavenworthii, 573-E, about 100 ft. long by 32 ft. wide, which had been planted March 31, 1936, was used in 1937 to compare three methods of handling perennial plantings of goldenrod.

The area was divided, across the original rows, into 12 plots, each 8 ft. by 32 ft. in size. All plots were fertilized (5% N - 9% P- 6% K) at the rate of approximately 800 lbs. per acre. Four of the plots were left undisturbed for controls, four were thoroughly cut up by running a weighted disc harrow three times across the original rows, and four plots were thinned by removing all plants from 2 ft. strips the full length of the plots. These 2 ft. cleared strips alternated with 1 ft. strips in which the plants were undisturbed. The choice as to which treatment each plot should receive was made by a process of randomization. The thinning and disking operations were carried out in March 1937 and the fertilizer was applied in May 1937. Cleared strips in the thinned plots were cultivated at regular intervals during the growing season. A 150 sq. ft. sample was harvested from each plot on September 30, 1937.

The mean yield of dry leaves per sq. ft. of the control plots was significantly greater than the mean yield of either of the other treatments. The mean yield of dry leaves per sq. ft. of the thinned plots was significantly higher than that of the disked plots. There was no significant difference between treatments in rubber per cent.

In rubber per square foot the mean yield of the control plots, was significantly greater than that of the disked plots but no greater than that of the thinned plots. There was no significant difference between the thinned and disked plots in rubber per square foot. (See Table 1).

As in 1935, the disking was apparently too drastic an operation, and killed a great many plants. Disking is also open to the objection that it does not provide for any effective means of cultivation and it was noted that weed growth was heavy in the plots which had been treated in this manner.

As pointed out above, the leaf yield of the thinned plots was better than that of the disked plots, but was still so far inferior to the untreated controls, that both the former treatments must be considered unsatisfactory.

The evidence available from the 1935 and 1936 experiments would seem to indicate that if a planting is to be carried over a second season, it should not be thinned or cultivated in any of the ways so far attempted.

TABLE I

	Thinned Plots	Disked Plots	Untreated Control Plots
Rubber Per Cent	4.31	3.71	4.47
Dry Wt. of Leaves per Sq. Ft. (in gms.)	9.9	8.8	12.9
Rubber per sq. ft. (in gms.)	0.432	0.327	0.575

- 1938 EXPERIMENT -

Since the 1936 and 1937 experiments had provided no direct comparisons between yields of first and second year plants, it was considered desirable to obtain data on this point. For this reason the 1938 treatment of old beds experiment was designed in such a way that yields and rubber content of variously treated second year plantings could be compared directly with first year plantings. At the same time this experiment afforded opportunity for comparing different methods of handling perennial plantings.

Experimental material consisted of fourteen 36 ft. rows, 24" x 8" spacing, of S. leavenworthii, 573-M, which were one year old at the

time the experiment was started, and four 36 ft. rows of the same variety planted adjacent to the above, at the beginning of the experiment.

The experiment was divided lengthwise into four 4 row blocks with guard rows between blocks. Each block was divided into 4 equal plots to provide 4 replications of each treatment. Plots were not randomized.

A 24 sq. ft. sample was taken from each plot for purposes of yield determination and rubber analysis.

Treatments were as follows:

Block 1 -- New Planting
Clean cultivation throughout the growing season.

Block 2 -- Second Year Plants
Ground near and under plants thoroughly stirred with subsoil plow early in the season and clean cultivated thereafter.

Block 3 -- Second year Plants
Untreated control, no thinning or cultivation of any kind.

Block 4 -- Second year plants
Same as block 2 except not subsoiled.

In blocks 2 and 4 the alleys between the original rows were kept open and free from weeds, though these alleys gradually became narrower due to thick growth of stolon shoots around the original plants.

The purpose of the subsoiling treatment given Block 2 was to loosen the soil which becomes more or less packed close to the plants where ordinary cultivation does not reach.

In Block 3, which was not cultivated or distrubed in any way, it was noted that the goldenrod was able to compete successfully with weeds. By mid-season goldenrod plants had practically filled up the original space between rows and all weed growth was choked out.

The yield of dry leaves per sq. ft. was much greater in all the second year plots than in the first year plots. These differences were very highly significant.

Of the three second year treatments the uncultivated, unthinned plots had a significantly higher yield of leaves per square foot than either of the other two.

There was no significant difference in mean leaf yield between Blocks 2 and 4.

On the other hand, the mean rubber per cent of all the second year plots was significantly lower than that of the first year plots.

Blocks 2 and 4 were significantly higher in rubber per cent than the uncultivated control block, but not significantly different from each other.

In spite of its very low rubber content, Block 3 (the uncultivated control) produced significantly more rubber per square foot than any other treatment.

Block 2 ranked second in rubber per square foot and significantly outyielded Blocks 4 and 1. Block 4 outyielded Block 1 by a highly significant margin.

Other differences between treatments were negligible with the exception of height. The mean height of the plants in Blocks 1, 2, 3, and 4 was respectively 175, 155, 115 and 150 cm.

The results of this experiment would seem to indicate that a goldenrod planting yields nearly twice as much rubber per square foot the second season after planting, as it did the first season, providing the plantings are not thinned or cultivated. Rubber content and plant stature were considerably lower the second year, but the greatly increased thickness of stand was more than sufficient to outweigh those deficiencies.

The lower yield of rubber per square foot of the cultivated blocks as compared with the uncultivated block, indicates that cultivation is not only a useless expense, but actually decreases yields in the second season.

The cultivated plots which received the subsoiling treatments were slightly superior to the cultivated plots which did not receive this treatment, in leaf yield and rubber per cent, and significantly superior in rubber per square foot. So apparently loosening the soil around the old plants was of some benefit, this point is only academic, however, since cultivation of any kind seems undesirable.

The same planting which was used for the 1938 treatment of Old Bed Experiment (Experiment #802) was carried on unchanged in 1939, for the purpose of securing data on leaf yield and rubber content the second and third season after planting. Each block received the same treatment as in 1938, with the exception of Block 1 which was left undisturbed in 1939, instead of being cultivated.

Sampling was carried out in the same manner, a 24 sq. ft. area being harvested from each plot.

TABLE II

Rubber Per Cent, dry weight of leaves per square foot, rubber per square foot and height of first and second year plants receiving different treatments. Experiment #802. S. leavenworthii, 573-N. Harvested September 20, 1938.

(Figures represent mean of 4 replications)

	Block 1 Planted 1939 Cultivated Only	Block 2 Planted 1937 Subsoiled and cultivated	Block 3 Planted 1937 Untreated Control	Block 4 Planted 1937 Cultivated Only		Necessary for Sig. between Means
Rubber Per cent	6.44	5.52	4.04	5.46	5%	0.42
					1%	0.61
Leaves per Sq.Ft.	7.04	12.96	20.08	11.82	5%	1.67
					1%	2.40
Rubber per sq. ft.	.454	.712	.812	.645	5%	.059
					1%	.084
Height (cm)	175	155	115	150		

Variance analysis of the data showed no significant difference between the second and third year uncultivated blocks in yield of leaves per square foot or rubber per square foot, but the second year block was significantly higher in rubber per cent.

The undesirability of cultivation was again conclusively demonstrated, as both control blocks outyielded the cultivated blocks to a highly significant degree, except in rubber content. The cultivated blocks were significantly superior in that character.

In 1939 the subsoiled and cultivated block (block 2) was superior to the cultivated block which did not receive the subsoiling (Block 4) in mean yield of rubber per square foot, but in 1939 the subsoiling was apparently detrimental, because Block 4 significantly outyielded Block 2.

A count of the number of stems per square foot showed that Block 3 had a significantly thicker stand than any of the other blocks. The other 3 blocks were not significantly different from one another in number of stems per square foot.

A direct comparison of the first season's yield of a given plot with

the yield of the same plot in subsequent years is more or less misleading because even though treated the same way both years, there is no accurate method of making corrections for climatic differences.

There were, however, certain relationships observed, which were probably not attributable to differences in weather conditions from year to year.

There was a consistent decrease in rubber content as the age of the plots increased, regardless of treatment. This decrease was more marked between the first and second seasons than in subsequent years.

There was a marked increase in leaf yield between the first and second seasons. In the uncultivated plots this high leaf yield was maintained in the third year, but in all cultivated plots third year leaf yields decreased sharply.

The net yield of rubber per square foot was greater the second year than it was in either the first or third years, regardless of treatment.

Results of work to date on handling perennial goldenrod plantings seem to indicate that it is best to cultivate for weed control the first season, and thereafter to leave the planting undisturbed.

When handled in this manner the goldenrod attains a very thick stand the second season and is able to compete successfully with weed growth. The second year plants are shorter in stature and lower in rubber content, than first season plants, but the total yield of rubber per square foot is much greater because of the increased number of plants.

Planting of this type may be successfully carried on through the third season without further attention, but yields are considerably lower. Peak yields are attained the second season after planting.

TABLE III

Rubber per cent, dry weight of leaves per sq. ft., rubber per sq. ft., no. of stems per sq. ft. and height of second and third year plants receiving different treatments. Experiment #901, S. leavenworthii 573-N. Harvested September 21, 1939.

(Figures represent mean of 4 replications)

	Block 1 Planted 1938 Cultivated in 1938 Untreated in 1939	Block 2 Planted 1937 Subsoiled & cultivated both years	Block 3 Planted 1937 Untreated both years	Block 4 Planted 1937 Cultivated both years	Necessary for sig. between means
Rubber %	3.89	5.08	3.34	5.10	5% .53 1% .75
Leaves per sq. ft. (grams)	19.15	4.98	20.82	7.88	5% 9.04 1% 12.68
Rubber per sq. ft. (grams)	.742	.253	.694	.399	5% .070 1% .097
No. of stems per sq. ft.	16.88	9.28	35.08	10.50	5% 7.97 1% 11.18
Height	180	125	150	135	

TABLE IV

Comparison of 1938 and 1939 rubber percent, yield of leaves per sq. ft. and yield of rubber per sq. ft. of 4 differently treated blocks in experiments #802 and 901. S. leavenworthii, 573-N.

(Figures represent mean of 4 replications)

		Block 1	Block 2	Block 3	Block 4
Rubber %	(1938	6.44	5.52	4.04	5.46
	(1939	3.89	5.08	3.34	5.10
Leaves per sq. ft.	(1938	7.04	12.96	20.08	11.82
	(1939	19.15	4.98	20.82	7.88
Rubber per sq. ft.	(1938	.454	.712	.812	.645
	(1939	.742	.253	.694	.399

- 1939-40 Experiment -

Twenty-five large plots of each of four superior varieties of S. leavenworthii were planted in March 1939, and retained through the 1940 season, to obtain comparative data on first and second year yields.

These plots were managed like Block 1 in experiment 802-901, i.e., cultivated the first season, but not disturbed, except for broadcast fertilization the second season.

Comparatively large samples were taken (50 sq. ft. from each plot) and this together with the unusually large number of replications of each variety (25), would tend to give considerable weight to the data from this experiment.

Statistical analysis of the data served to confirm the findings of previous investigations along the same line.

In every case, second year leaf yields were significantly higher. With one exception, second year rubber percentages were significantly lower, and this exception is readily accounted for by the fact that these plants (3S-91) were attacked by disease in 1939 but not in 1940.

Despite lower rubber content the second season, yield of rubber per square foot was significantly higher than during the first year. (See Table V).

As mentioned above, these results definitely confirm previous conclusions, and it may be taken as rather well established that the yield of rubber per square foot of perennial goldenrod plantings is greater the second season after plantings than the first season, even though rubber content is lower.

It may also be concluded that thinning, soil stirring or cultivation of any kind is detrimental after the end of the first growing season. Undisturbed perennial plantings have proved able to compete successfully with weed growth.

TABLE V

Net Dry weight of leaves per sq. ft., Rubber per cent and Rubber per sq. ft. of 4 varieties of S. leavenworthii in 1939 and 1940, in experiments #903 and #4005.

(Figures represent mean of 25 replications)

	3S-91		3S-4		3S-40		3S-79		Difference
	1939	1940	1939	1940	1939	1940	1939	1940	Necessary for 5% sig.
Leaves per sq. ft. (gms)	*5.54	10.08	10.16	14.44	6.32	10.98	9.22	11.96	1.52
Rubber Per Cent	*4.94	4.96	3.79	3.38	5.59	4.99	5.03	4.38	0.288
Rubber per sq. ft. (gms)	.274	.496	.383	.487	.351	.541	.459	.521	0.061

*Note: 3S-91 was diseased and abnormal in 1939 but was disease free in 1940.

SELECTION AND BREEDING

Efforts toward improving the rubber yielding capacity of goldenrod have been directed chiefly along two lines, viz; mass selection and hybridization. The two phases of the work have been carried on continuously since the inception of the project at Savannah in 1935, but during 1939 and 1940 more attention has been given to synthetic production of new types through hybridization. Establishment of selfed lines which may eventually become homozygous for certain characters, has also been stressed in the more recent work.

The fundamental aim of the goldenrod breeding work has been to increase the net yield of rubber per acre and methods of approach naturally have been dictated by the genetic characteristics of the plant.

Since goldenrod is normally cross-pollinated, it is quite heterozygous as to most of the characters studied. Another characteristic which has added to the difficulty of breeding desirable types is that the factors for high rubber content and heavy leaf yield are never found in the same individual. In other words, there is an extremely high negative correlation between rubber per cent and leaf yield.

The heterozygous genetic constitution of the plant was responsible for the belief that improvement could be accomplished by means of mass selection. This was the basis for the earlier work, which consisted mainly of growing large numbers of seedlings from open pollinated seed, and selecting outstanding individuals. These individual plants were increased vegetatively, and the resulting clones were compared with older varieties. Most of the breeding work done by the Edison organization at Fort Myers, Florida, was of this type, as was the bulk of the earlier work at the Savannah station.

It has been standard practice here, to grow a vegetatively propagated row of the same variety alongside each row of seedlings from which selections are to be made. The mean yield of the vegetative row serves as a standard for judging the performance of the seedlings. In most instances seedlings have not been selected for increase and further testing unless they exceeded the mean plus twice the standard deviation of the comparable vegetative row in either rubber percent or leaf yield. Disease resistance, tendency to lodge, vegetative habit , and other characteristics, have usually been taken into consideration as well as yield and rubber content. A few seedlings have been selected for certain special reasons.

In the above manner, a total of 99 new clones have been originated at Savannah since 1935. These new clones are, of course, thoroughly tested for several years before being finally adopted as standard varieties. (See section on Variety Testing).

Of the 99 tentative selections made during the past 3 years, only 3 have been retained, and only 1 of these 3 is definitely outstanding. It is a 1936 selection, known as 6S-30, and is a very distinct type, having some of the characteristics of the altissima species. It is quite possible that it might be a natural hybrid between leavenworthii and altissima. 6S-30 has ranked No. 1 for 3 years in succession in both leaf yield and yield of rubber per plant among the varieties grown in the randomized, replicated, variety test. Unfortunately it is rather low in rubber content, lodges badly in strong winds, and is below the average in stolon production.

Results to date would seem to indicate that very little additional improvement can be expected from a continuance of mass selection. In fact, the limitations of this technique have been recognized for some time, hence the recent emphasis on hybridization.

The purpose of hybridization is, of course, to develop a new and superior type of recombining the desirable characteristics now possessed by several of the better varieties.

There are some goldenrod varieties characterized by a high rubber content, and others which are outstanding in leaf yield, but there is no one variety which is superior in both respects. Those varieties which rank highest in leaf yield are poor, or at best, mediocre in rubber content, and the varieties which have the best rubber percentage are invariably low in yield of leaves.

Therefore, one of the objects of the hybrilization project has been to combine high rubber content and high leaf yield in a single individual, by crossing varieties having good rubber content with those possessing superior leaf yield.

Another objective has been to concentrate the factors for high rubber content in a single individual by crossing two varieties which, though very different in vegetative habit, are both consistently high in rubber per cent.

Similarly, two different varieties which both rank high in leaf yield, were crossed in an attempt to combine leaf yield factors in a single plant.

Reciprocal crosses were made in all cases, to eliminate certain possible chances of failure, such as pollen sterility, etc.

In as much as goldenrod is heterozygous for certain important characters, it was thought desirable to establish some inbred lines, in an effort to approach homozygosity for such characters as rubber content, stolon production, etc.

Choice of the varieties to be used in these crosses was based on performance in variety tests over a period of years.

In 1939 6S-30 and 3S-4 were selected as the two most outstanding varieties from the standpoint of leaf yield. Both 6S-30 and 3S-4 are comparatively low in rubber per cent.

3S-79 and 3S-91 were chosen on account of their high rubber content, having been consistently good performers in all tests. They are both rather poor in leaf yield.

Following is a list of the crosses and self-pollinations made in 1939:

Crosses		Selfed
3S-4 x 6S-30	3S-79 x 3S-4	3S-4
3S-4 x 3S-79	3S-79 x 6S-30	
3S-4 x 3S-91	3S-79 x 3S-91	6S-30
6S-30 x 3S-4	3S-91 x 3S-4	3S-79
6S-30 x 3S-79	3S-91 x 6S-30	
6S-30 x 3S-91	3S-91 x 3S-79	3S-91

The 1940 Breeding program was similar to that of 1939, except that S. altissima was included in order to obtain interspecific crosses. 3S-4 was dropped from the project because of poor reproductive characteristics.

A list of the 1940 crosses and self-pollinations follows:

Crosses	F Hybrids Selfed	Selfed (1st Gen.)	Selfed (2nd Gen.)
6S-30 x 3S-79	4S-27 x 3S-162	3S-79	4S-27
6S-30 x 3S-91	3S-162 x 4S-27	3S-91	3S-91
6S-30 x S. Altis.	4S-27 x 3S-91	6S-30	3S-162
	3S-91 x 3S-162		
3S-79 x 6S-30	3S-91 x 4S-27		
3S-79 x 3S-91	3S-162 x 3S-91		
3S-79 x S. Altis.	Altis x Leavenworthii (6S-32)		
	Serotina x Leavenworthii (6S-34)		
3S-91 x 6S-30			
3S-91 x 3S-79			
3S-91 x S. Altis.			

The floral structure and behavior of goldenrod is such as to render the necessary breeding operations, particularly emasculation, very difficult and tedious. The small size of the flowers is one characteristic

which adds to the difficulty of manipulation. For example, a typical head of Solidago leavenworthii which is approximately 7 to 8 mm long and 2 mm. wide, normally contains ten to twelve disk florets and fifteen to eighteen ray florets, a total of 25 or 30 individual flowers.

The ray florets are pistillate, and of course do not require emasculation. They usually open a day or so ahead of the first disk florets. The disk florets are perfect, and must be emasculated shortly after they open, and before pollen is shed.

As is typical of many composites, the disk florets do not all open at the same time, but 2 to 5 per day open over a period of 3 or 4 days.

If weather conditions are normal, the disk corollas open about 9:00 AM. As soon as the corolla is open the style begins to elongate rapidly. At this stage of development the stigma is surrounded by the anthers which are attached to each other in the form of a sheath or envelope, closed at the apex. The elongating style carries the anther envelope upward until both stigma and anthers are extruded considerably beyond the corolla tube. Between 11:00 A.M. and 12 noon the apex of the anther envelope opens, and a mass of pollen is pushed out by the continued elongation of the style. As soon as pollen is shed, the filaments slowly retract, and the anthers are partially withdrawn into the corolla tube, leaving the stigma fully exposed.

The outer surface of the bifid stigma is apparently not receptive, otherwise self-pollination would take place while the stigma is enclosed in the anther envelope.

After the staminate stage has passed, the stigma lobes gradually spread apart to expose the receptive inner surfaces. For the first day or two the lobes remain confluent at the extreme apex, while separated below. However, if pollination does not take place promptly, the lobes spread farther apart until they are no longer touching at the apex. No studies have made to determine the exact stage at which the stigma is most receptive. However, it is known that when pollination does not occur, stigmas will remain turgid and apparently receptive for as long as two weeks.

In order to protect the flowers from indiscriminate pollination by insects, a special type of bag was used. The material used in making the bags was a very small-mesh cheesecloth, and two thicknesses were used. The bags were made up in the form of a sleeve, or cylinder, open at both ends. To support the cheesecloth, and prevent it from collapsing in folds about the inflorescence, a cylindrical wire frame was employed. These frames were 7inches in diameter and 12 inches

in height, and were made of 1/2" mesh wire cloth. The cheesecloth sleeves were slipped over these frames, thus forming a 7 x 12 inch bag which was sufficiently large to enclose an average goldenrod inflorescence.

To facilitate handling the bags and to keep them out of the way while work was being done on the flowers, a cord was attached to the upper end of the wire frame, and passed over two smooth, overhead rods which served in place of pulleys. A counterweight of approximately the same weight as the bag, was attached to the other end of the cord. The bag could then be raised or lowered at will, and the counterweight would hold it in any desired position. Thus the stem of the plant did not have to support the weight of the bag, and it was found very convenient to have the bag held out of the way while manipulating the flowers.

The bags were closed to exclude insects by tying the upper end around the supporting cord, and the lower end around the stem of the plant.

The temperature inside bags of this type was found to be considerably lower than in cellophane or kraft paper bags, and circulation of air was very much better.

The thorough removal of all pollen produced by the flowers which is to be used as females is, of course, a prerequisite of any controlled cross. To accomplish this end it is customary to remove the anthers before they have dehisced. The floral structure of many plants is such that this operation may be carried out while the flowers are still in the bud stage, but flowers of the compositae in the bud stage, are grouped tightly together in compact heads, and manipulation of any individual bud is extremely difficult if not impossible, therefore, it is necessary to wait until the flower is open to emasculate it, and at this stage the anthers have already dehisced. Fortunately the pollen is not shed at once, but is retained for a time in the sheath or envelope formed by the five united anthers. The actual discharge of pollen does not take place until the stigma pushes up through this anther envelope, and forces pollen out the upper end.

Since the pollen is in a loose mass, it cannot be removed with instruments, and a fine stream of water under moderate pressure has been found effective for removing it.

The emasculation technique employed in the goldenrod work, was essentially that of Oliver (1), though a portable hydraulic pressure unit developed by the writer, was used. This unit, which has been described in detail elsewhere, consists of a small garden sprayer

of the vertical, continuous type, with a 1/4 inch hose outlet, and a hypodermic needle as a nozzle. (1) Oliver, G. W. "NEW METHODS OF PLANT BREEDING", U.S.D.A. Bur. Plant Ind., Bulletin #167. It is controlled by means of a foot pedal, in order to leave both the operators hands free. The stream discharged by a hypodermic needle proved to be adequate, and ample pressure was easily obtained with this type of pump.

While very efficient for washing away loose pollen, the force of the stream of water was not always sufficient to rupture the anther envelop, hence, in order to make sure that no pollen grains remained in the envelope, this envelop was slit longitudinally with a fine pointed needle, prior to the washing operation. A binocular head loupe of 3X magnification was used during these operations, and each flower head was carefully examined after emasculation to make sure that no pollen remained.

As mentioned above, the florets open about 9:00 A. M., and usually begin to shed pollen about 11 or 11:30 A. M. The anthers were found to be sufficiently extruded to allow manipulation by about 10:00 A. M., but had not yet begun to shed pollen, therefore, emasculation operations were begun about 10:00 A.M. and finished by 11 or 11:30 A.M. since it is desirable to complete emasculation each day before pollen shedding begins, it was necessary to limit the size of the breeding project to the number of inflorescences that could be emasculated in approximately one hour. By removing most of the inflorescence and leaving only 6 or 8 flower heads on any one plant, the number of plants available for use as females may be increased. The number of seed from any one cross is, of course, reduced, but this was unavoidable, as it was essential to have at least 12 female plants to carry out the desired program and it was found that one operator could not emasculate 12 plants in an hour unless the number of heads per plant was drastically reduced.

As mentioned above, the 10 or 12 disk florets of any one head do not all open on the same day. Therefore, it was necessary to repeat the emasculation operation each day for 3 or 4 successive days, or until all the disk florets in the head had opened and been emasculated.

Pollen for the crosses was obtained from plants grown in the greenhouse especially for this purpose. During the 1939 season, pollen was collected in the morning between 9 and 10 A.M. at this time of day the anthers are extruded and have dehisced, but no pollen has been shed. Pollen collected in small glass vials, by holding the flowers over the vials and "teasing" the anther envelope with a needle. Another method used was to collect the anther envelope intact with forceps, and dissect them to release the pollen. This method was tedious and slow, but less wasteful than the former.

When pollen is collected at the time of day mentioned, it is not necessary to bag the plants, because the pollen is still enclosed in the envelope, and there is little chance of contamination even though insects are present. However, in 1940 all pollen plants were bagged to avoid even a remote chance of contamination. Bagging has the further advantage that pollen may be collected at any convenient time of the day.

The stage at which the stigmas are most receptive has never been exactly determined. However, it is known that when pollen is withheld, the stigmas remain fresh looking and apparently receptive for from 10 days to 2 weeks. So it may be assumed that pollination could occur at any time during this period.

In most instances pollen was applied within a day or two after emasculation was completed. The transfer of pollen from collection vial to stigma was effected with a small camel hair brush. The brush was thoroughly sterilized in alcohol and examined before changing from one variety of pollen to another.

Fertilization, which is indicated by shriveling and browning of the stigma, did not always occur as a result of the first application of pollen. In such cases pollen was applied a second time, and in a few instances a third application was necessary.

In 1939 and 1940 the goldenrod varieties included in the breeding project flowered during the latter part of September and the first two weeks of October under greenhouse conditions, and all breeding work was done during this period.

Three experiments were conducted to determine the effect of Colchicine on goldenrod, S. leavenworthii, variety 3S-91 being used. Stolen cuttings were treated in two of the experiments, and in the other experiment the treatment was applied to stolon shoot terminals.

The cuttings were soaked in a 0.1% aqueous solution for periods ranging from 1/2 hour to 24 hours. The shoots were treated by immersing their terminals in the same solution for from 2 to 6 hours.

After treatment the cuttings were rooted in sphagnum moss, and later transferred to pots in the greenhouse.

Treatment of cuttings in a 0.1% solution for any periods longer than 2 hours was found to be lethal. The treated cuttings which survived were much slower in rooting than the untreated control cuttings, and were definitely stunted.

The same stunting effect was observed on the treated shoots, and was

more pronounced among the plants which received the longer treatments. A very pronounced tendency toward profuse branching and prolific stolon production, was also noted among the longer treated groups.

Normal flowers and viable seeds were produced by all colchicine treated plants that survived. Seedlings grown from open-pollinated seed produced by these plants, were tested in side-by-side comparison with untreated stocks of the same variety, and no significant differences could be observed.

Pollen grains produced by treated plants were examined microscopically and measured with an eyepiece micrometer, but none were observed which differ significantly in size or general appearance from the pollen of untreated plants of the same variety.

Goldenrod seeds have been treated by soaking in aqueous colchicine solutions for various lengths of time, but such treatment has invariably proved to be lethal.

The most noticeable results of the colchicine treatment so far attempted have been to inhibit growth rate and induce proliferation of branches and stolons. No desirable variants have been produced.

SUMMARY

Breeding work for the purpose of improving the rubber yielding capacity of goldenrod has been carried on at Savannah from 1935 to 1940.

The earlier work consisted chiefly of mass selection among large heterozygous populations grown from open pollinated seed. 99 new varieties have been originated by vegetatively increasing single superior plants selected in this manner. Most of these new types have been eliminated by rigid variety testing, but three of them have shown considerable merit, and one of the three is definitely outstanding.

During the past 2 years, emphasis has been placed on the development of new types through hybridization and a large number of controlled crosses have been successfully made.

Most of the crosses have been between varieties having a high rubber content and varieties having a heavy leaf yield, in an effort to combine the two characters in a single individual.

Strains with a superior rubber content have been crossed with different types that also have a high rubber content in an attempt to concentrate the factors for rubber production in a single individual. Different heavy leaf yielding strains have also been hybridized to concentrate the factors for the latter character.

Selfed lines have been established for the purpose of eventually developing strains that approach homozygosity for certain desirable characters.

The floral structure and pollination mechanism of goldenrod has been the subject of detailed study.

A specialized technique has been developed for making controlled crosses, and a new type hydraulic emasculator has been designed and successfully used.

Colchicine treatment of goldenrod plants, cuttings and seeds has been tried, but no desirable variants have been produced.

A very fine stream of water under moderate pressure, directed against the anthers, has proved to be a very effective method of emasculating goldenrod. (Solidago spp.).

It is thought that this technique was first applied to goldenrod by Mr. H. G. Ukkleberg, when in charge of goldenrod investigations for the Edison Botanic Research Corporation at Fort Myers, Fla.

A portable, foot-controlled apparatus, which will deliver a stream of water of the required volume and pressure, has been designed by the writer, for use in connection with goldenrod breeding work at the U. S. Plant Introduction Garden, Savannah, Georgia.

The principal piece of equipment used in the construction of this apparatus, was a two gallon, brass, garden sprayer, of the vertical, continuous type. Air pressure is built up by operating a plunger in the top of the tank, and water is forced out through a hose outlet, which is also in the top of the tank. The tank is 17" tall and has a diameter of 6".

Attached to the hose outlet is a short length of 1/2" rubber hose with a grip-type shut-off valve at the end. In place of the spray rod or nozzle which is commonly screwed on to the shut-off valve casting, a reducing fitting with a $\frac{1}{4}$" hose coupling, was installed. A ten ft. length of $\frac{1}{4}$" rubber tubing of the type ordinarily used on automobile windshield wipers, was attached to this hose coupling.

A Luer pattern hypodermic needle (1" length, 22 gauge) was soldered into the end of a 4" length of 1/4" copper tubing. This metal tube provides a convenient means of attaching the needle to the rubber tubing, and also acts as a rigid handle which facilitates directing the stream of water. It fits snugly into the rubber tubing and if slipped in an inch or more, makes a water-tight joint without the use of clamps.

It was found that both hands were needed to direct the stream of water and hold the flower head, so foot control of the shut-off valve was provided by attaching this valve rigidly to the side of the tank, and operating it by means of a foot treadle. The valve was held in place by means of a 1" x 2" board, 17" long, which was fastened in a vertical position on the side of the tank by iron straps at the top and bottom. An indentation the exact size and shape of the shut-off valve casting was made in this board, and the valve was held in place in the indentation by fastening a removable wooden strip over it.

A strap iron treadle about 6" long was pivoted on the upright board near the bottom of the tank, and connected to the handle of the shut-off valve by means of a metal rod.

A 10" x 12" wooden base was attached to the bottom of the tank to prevent overturning or tipping.

VARIETY TESTING

The testing and comparison of various goldenrod varieties, or selections, at the Savannah station was begun in 1934. In that season 12 different species, including 144 selections, were grown for the purpose of obtaining comparative data on yield, rubber content, and content and growth characteristics. 115 of these selections were obtained from the Edison Botanical research Corporation, of Fort Myers, Florida, and the remaining 29 selections came from the U. S. Acclimatization Field Station, Charleston, S. C. All these selections were really clones, or in other words, vegetative increase of a single plant.

Each selection was grown in an unreplicated, single-row plot, and data were obtained on the height, height to first green leaf, branching characteristic, floral maturity at harvest time, net yield of dry leaves per plant and percentage of rubber contained in the leaves. Five plant bulk samples were taken to represent each plot. In harvesting samples, the plants were cut off at ground level, leaves stripped off by hand, dried, and sent to Washington for rubber analysis. Stems were discarded. In 1935 numerous new selections were obtained from the Edison Corporation, bringing the total number of leavenworthii selections under investigation up to 220. More than a hundred different selections of less important species were also being studied at this time.

During 1935 and 1936 the variety testing technique employed was similar to that described for 1934 except that detailed data was obtained on such characters as, leaf length and width, number of leaves on 30 cm. of stem, No. of stolons per hill, condition, lodging, disease, etc.

Since limitations of land and personnel precluded replicated tests with such a large number of selections, it was decided in 1937 to eliminate all selections which had shown no special merit.

Only two characters were taken into consideration in the elimination process, namely Rubber per cent and net dry weight of leaves yielded per plant.

The first step in the process was to calculate the mean rubber per cent of the 220 selections in 1935, also the mean yield of leaves per plant. Growing conditions in 1935 were rather adverse, and the mean yield of leaves per plant was comparatively low (12.4 gm) while the mean Rubber per cent was (5.09).

The same 220 selections were grown in a different location in 1936 but the spacing, method of harvesting, analysis, etc.,was the same. Weather conditions were much more favorable for vegetative growth in 1936, however, and the mean yield of leaves per plant was much higher (20.9 gm) while the mean rubber per cent was lower (4.03%).

The next step in the process was to eliminate each selection whose 1935 rubber per cent was below the 1935 mean (5.09%) or whose 1936 Rubber per cent was below the 1936 mean (4.03%), a list of selections retained at this stage of the process (List 1) contained all those whose rubber per cent was above the mean in both years, regardless of leaf yield.

The performance of the 220 selections was then checked in exactly the manner described above, except that mean yield of leaves per plant was used as the standard instead of mean Rubber Per cent. (List 2), of course, contained all selections whose leaf yield was above the mean in both years, regardless of Rubber per cent. It was found that nine selections appeared in both (List one) and (List two) indicating them to be outstanding in both Rubber per cent and leaf yield. They were designated A selections. Seven of the A selections had been tested in replicated comparisons (Expts. #619 or #620) and six of the seven ranked first in Rubber per plant in their respective comparisons, and the other was above the mean of the comparison in which it was grown.

All selections in (List 1) which exceeded the mean Rubber per cent Plus 2 S.E. of the A selections in both 1935 and 1936 were retained and designated B selections.

All selections in (List 2) which exceeded the mean yield of leaves per plant plus 2 S.E. of the A selections in both 1935 and 1936 were retained and designated C selections.

M selections are those which did not meet the standards of progeny row performance, but for some reason or other were considered good enough to warrant further testing.

Thus four types of selections were retained for further testing:

A - above the mean two years in both rubber per cent.
B - High rubber per cent regardless of leaf yield.
C - High leaf yield regardless of rubber per cent.
M - Below progeny row performance standards but retained for some special reason.

Lists of four types follow:

A Selections	B Selections		C Selections
3S-4	3S-7	573-B	3S-69
3S-5	3S-50	573-C	4S-15
3S-65	3S-58	573-1	4S-54
3S-227	3S-79	573-L	4S-61
4S-3	3S-82		573-E
4S-9	3S-85		573-J
4S-25	3S-162		
4S-27	4S-20		
573-F	4S-59		

M Selections

3S-40 did not meet requirement of progeny row performance but was significantly higher than either control in Rubber per plant in Expt. #620 TS-4 S-4 and was the only selection in Expt. #620 which was significantly higher than either control.

3S-15 did not meet requirements of progeny row performance in 1936 but was outstanding in Expt. #620. 3S-91 did not meet requirements of progeny row performance, but was outstanding in Expt. #620. 3S-33, 3S-37 and 3S-199 above the mean in both rubber per cent and leaves per plant at Fort Myers in 1934, 1935, and 1936 and were above the mean in either Rubber per cent or leaves per plant in 1935 and 1936 at Savannah.

The 34 selections listed above were all planted in the 1937 replicated progeny section. In addition to these, there were 17 other selections of S. leavenworthii retained for various reasons, and planted in the single row progeny section.

5S-1	5S-4	5S-7	5S-10	573-U	3S-99
5S-2	5S-5	5S-8	5S-11	573-M	3S-111
5S-3	5S-6	5S-9	573-A	3S-248	

The 5S selections could not be compared with the others as they had only been grown one year and were retained in order to obtain another year's data.

573-A a very distinct wide-leaf type which is the seed parent of several superior selections.

573-U is a distinct type which has a very good leaf yield but low Rubber per cent.

573-M was used in one of the experiments and it was thought desirable to have it represented in the progeny section as a check.

3S-248 met the requirements for C selections but was eliminated from that list because of poor reproductive capacity.

3S-99 and 3S-111 were retained because of high rubber per cent on low ground in 1935.

Exactly the same method was followed in eliminating the Edisoniana selections, and out of 64 selections grown in 1935 and 1936 fifteen were retained as follows.

A-Selections	B-Selections	C-Selections
3S-319	3S-313	3S-302
3S-376	3S-335	3S-305
3S-380	4S-105	3S-377
		4S-100

M-Selections.	
3S-353	Selections
4S-103	which fall slightly
4S-117	short of B and C
4S-121	
4S-119	

No formal method was followed in eliminating selections in the minor species, but in most of them the three best selections from the standpoint of rubber per cent and leaves per plant in both 1935 and 1936 were retained unless they showed some undesirable characteristic such as disease susceptibility, tendency to lodge, etc. Selections retained as follows:

S. Nashii	S. Altissima	S. Fistulosa
3S-415	*a Savannah River Sel. 3S-452	3S-445
4S-63 35-421	*b R. I. 733 Pl. 8	3S-402
*Hand 30 Fla. 9		4S-400
3S-416		
*carried for Genetic reasons	*a Leaf yield *b Rubber %	

S. Serotina
R. I. 724 Pl. 30
R. I. 724 Pl. 15
R. I. 724 Pl. 14

S. mirab.	S. elliottii	S. sempervirens
3S-401	4S-300	Gibbs Fla. 3(Leaf
4S-200	* SPC #5	Hand 30 Fla. 10 yield)
	3S-412	Fla. 322-A
	* 1936 performance	

Other minor species in which no selection work has been done, are represented by a single type, or in a few cases, seedings from two different localities as follows:

S. rugosa	S. petiolaris	S. speciosa
S. ulmifolia	S. brachyphylla	S. squarrosa
S. odora	S. Serotina gigantea	S. gramnifolia Var. Nuttallii
S. erecta	S. randii	S. sphacelata
S. neglecta	S. nemoralis	S. caesia
S. rigida	S. Hirtella	S. arguta
S. ridellii	S. gillmanii	
S. canadensis	S. racemosa	

Three hybrid varieties from England, Schwefelgeisir, Gold Wings and Perkeo.

The investigations in 1934, 1935 and 1936 had shown rather definitely that the leavenworthii species was superior to all others, as a rubber producer. Therefore, beginning in 1937 intensive variety testing was confined to the leavenworthii species, and an improved field plot technique was adopted. This technique consisted of growing 5 or 6 replications of each variety.

The location within the experimental area, which each replication was to occupy, was determined by a process of randomization. This type of experimental design is known as the randomized block plan, and is considered standard agromoic practice. Data obtained from experiments of this kind are well adapted for statistical interpretation by the analysis of variance method.

Starting in 1937 with 34 selections, the number tested each year has been gradually reduced as the less desirable ones were eliminated, until in 1940 only 15 selections remained. Of these 15 superior selections, seven have yield significantly above the mean in either weight of leaves per plant, rubber per cent, or rubber per plant for 4 years straight.

These seven selections are: 4S-15, 4S-61 and 573-E, superior in leaf

yield; 3S-37 and 4S-59, superior in rubber per cent; 3S-65 superior in rubber per plant: and 3S-79 superior in both rubber per cent and rubber per plant.

6S-30 must certainly be included among the outstanding selections, even though only 3 years'data are available, because it has ranked No. 1 in both leaf yield and rubber per plant every year it was tested. Its chief drawbacks are low rubber content, tendency to lodge, and relatively poor stolon production.

4S-59 has been the most consistently high in rubber content during the four year testing period, but its leaf yield is relatively poor.

3S-79 must be considered the best all around selection, as it has been consistently high in both rubber per cent and rubber per plant throughout the testing period, and has no undesirable vegetative characteristics.

Single row plots of all the minor species referred to above, have been carried throughout the testing period for visual comparison, and to maintain stocks for possible genetic requirements. Many of these minor species have failed to become acclimated to local conditions, and have died out. In 1940 those surviving were:

S. edisoniana
*S. nashii
S. altissima
S. fistulosa
S. serotina
S. elliottii
S. sempervirens
S. mirabilis
S. ulmifolia
S. neglecta
S. petiolaris
S. serotina gigantea
S. randii
S. nemoralis
S. speciosa
S. gillmanii
Brachychaeta sphacelata
S. Rugosa

*Note: S. nashii, formerly given specific rank, is now considered by some authorities to be a variety of S. leavenworthii.

The variety testing work carried on at Savannah has not been limited to a comparison of selections received from other stations. A number of promising new types have been developed as a result of the selection and breeding operations carried on here, and it has been a regular procedure to include these new types in the randomized block test for direct comparison with established varieties.

It has been the policy to carry a new selection in the randomized

blocks for at least two years before making a final decision as to its merit. This is because a single season's performance may be misleading due to abnormal conditions.

SUMMARY

Two distinct techniques have been employed in the variety testing work at Savannah, to wit: single row plot comparison, and randomized, replicated blocks.

The earlier work was confined to the single row plot comparisons, but during the past 4 seasons the randomized block experimental plan has been employed to obtain more accurate data on comparative yield and rubber content.

Many different species of goldenrod have been tested and compared but none has proved equal to Solidago leavenworthii as a rubber producer for this locality.

220 different varieties of leavenworthii which were obtained from other sources, and nearly 100 selections originated at this station have been studied during the 7 year period that variety testing work has been carried on.

All but 15 of these varieties have been eliminated for one reason or another, and 3 of the 15 have proved to be definitely superior.

A considerable proportion of the minor species tried out, have proved poorly adapted to local conditions, and have failed to survive.

VARIABILITY OF SEEDLINGS AND CLONES

A number of experiments have been conducted to determine the degree of diversity present in seedling populations grown from open-pollinated seed, and to ascertain whether or not such seedling populations are more diverse than clones of the same variety.

Seedling populations and vegetatively propagated populations of 8 varieties of Solidago leavenworthii were compared on the basis of rubber per cent in 1935, and it was found that the mean coefficient of variability of the seedlings was 20.075 per cent, or almost twice as large as that of the clones, which was 10.778 per cent. This difference between means is highly significant.

In 1936 seedlings and vegetatively propagated populations of two varieties of Solidago leavenworthii (573-A and 573-R) were compared on the basis of rubber per cent, leaf yield, height, leaf length, and

leaf width. These tests were carried out by planting 50 seedlings in a single row adjacent to a row containing 50 stolon shoots of the same variety. Height and leaf size measurements were made on each plant late in the growing season, and each plant was harvested and analyzed individually.

The coefficient of variability of each population was determined for each of the five above-mentioned characters, and it was found that the diversity of the seedlings was greater in every case than the diversity of the comparable clone.

For the 5 characters under consideration, the mean coefficient of variability of the 573-A seedlings was 19.23 per cent, as against 14.67 per cent for the vegetatively propagated plants of the same variety. For 573-R, the comparable coefficients of variability were 21.27 per cent and 14.18 per cent, respectively.

Leaf yield was much more variable than any other character studied, and height was the least variable. This was true of both seedlings and clones of both varieties.

In 1938 seven varieties of S. leavenworthii were compared in the same type of experiment as that described for 1936. They were: 3S-4, 3S-5, 3S-40, 3S-69, 3S-79, 3S-91 and 4S-27.

Coefficients of variability were calculated for both seedling populations and clones of each variety, on the basis of leaf yield, rubber per cent and rubber per plant. (See Table 1).

The mean variability coefficient for each character (all varieties) was also determined for seedlings and clones separately (See Table II). Statistical analysis of these data indicated that seedling populations of these particular varieties were not significantly more diverse than the clones.

The 1940 experiments which were conducted for the purpose of comparing seedling, and clonal diversity, indicated that the two types of populations were equally variable as to leaf yield and rubber per plant. However, the seedlings were significantly less uniform in rubber content. (See Tables 3 and 4).

This greater diversity of seedlings in the rubber content character was true of all four varieties grown in the 1940 comparison, but was less marked in the 6S-30 variety than the other three.

Since there is a definite lack of agreement in the available data, no valid conclusion can be drawn regarding the relative diversity of seedling populations and clones. Further investigation along this line is indicated.

TABLE I

Coefficients of variability of seedling populations and clones of seven varieties of Solidago leavenworthii in experiment #807

		Seedlings	Clones
3S-4	(Weight of leaves per plant	29.62	33.76
	(Rubber Per cent	13.74	12.34
	(Rubber per plant	29.07	31.05
3S-5	(Weight of leaves per plant	31.26	34.87
	(Rubber per cent	14.24	18.03
	(Rubber per plant	30.14	29.97
3S-40	(Weight of leaves per Plant	32.88	23.40
	(Rubber per cent	11.60	9.04
	(Rubber per plant	31.08	24.14
3S-69	(Weight of leaves per plant	33.06	41.88
	(Rubber per cent	12.16	10.51
	(Rubber per plant	32.50	41.38
3S-79	(Weight of leaves per plant	36.44	27.03
	(Rubber per cent	9.84	5.68
	(Rubber per plant	35.08	40.67
3S-91	(Weight of leaves per plant	38.03	40.28
	(Rubber per cent	15.28	12.19
	(Rubber per plant	35.44	38.54
4S-27	(Weight of leaves per plant	31.73	24.97
	(Rubber per cent	15.86	7.47
	(Rubber per plant	31.60	23.62

TABLE II

Mean variability coefficients for weight of leaves per plant, rubber per cent and rubber per plant of seedling. Populations and clones of seven varieties of S. leavenworthii in experiment #807.

	Seedling Coef. of Var.	Clonal Coef. of Var.	Value of F	F. Value necessary for 5% significance
Wt. of Leaves per plant	33.29	32.31	0.106	4.75
Rubber Per Cent	13.25	10.75	2.12	4.75
Rubber Per Plant	32.13	32.77	0.044	4.75

TABLE III

Coefficients of variability of seedling populations and clones of four varieties of S. leavenworthii in experiment #4003

		Seedlings	Clone
3S-4	(Weight of leaves per plant	30.94	37.90
	(Rubber per cent	15.72	9.41
	(Rubber per plant	33.95	34.65
3S-79	(Weight of leaves per plant	29.83	34.65
	(Rubber per cent	14.67	9.32
	(Rubber per plant	30.64	35.69
3S-91	(Weight of leaves per plant	52.51	33.71
	(Rubber per cent	19.01	11.20
	(Rubber per plant	39.97	38.82
6S-30	(Weight of leaves per plant	42.47	46.11
	(Rubber per cent	15.02	14.37
	(Rubber per plant	38.82	46.83

TABLE IV

Mean variability coefficients for weight of leaves per plant. Rubber per cent and rubber per plant of seedling populations and clones of four varieties of S. leavenworthii in experiment #4003.

	Seedling Coef. of Var.	Clonal Coef. of Var.	Value of F	F. value necessary for 5% Significance
Weight of leaves per plant	38.94	38.09	0.020	5.99
Rubber per cent	16.10	11.07	10.63	5.99
Rubber per plant	35.84	39.00	0.81	5.99

VARIABILITY WITHIN A CLONE

In 1939 an experiment was carried out to furnish information on the causes of the wide variability in rubber yield often noted among individuals of the same clone.

It was suspected that this variability was due, at least in part, to the variable numbers of stolon shoots produced by the different individuals. Therefore, the experiment was planned chiefly for the purpose of evaluating the influence of stolon shoots.

The experimental material consisted of 150 plants of S. leavenworthii, 573-C, arranged in 3 adjacent rows of 50 plants each. The rows were 30 inches apart, and plants spaced 8 inches apart in the row.

Row 1 was used as a control, each individual plant including all its attached shoots being harvested and analyzed separately.

In row 2 all stolon shoots were cut off at the surface of the ground as soon as they appeared, only the original, main stem being allowed to develop. Each stem was harvested individually.

Row 3 was allowed to develop normally, and no shoots were removed but only the main stems were harvested.

In this manner it was possible to obtain direct leaf yield and rubber content comparisons between main stems grown with and without stolon shoots, and also to compare main stem yields with yields of entire plants of the same clone.

It should be noted that most of the plants in the experiment were severely infected with mid-stem disease, which destroyed all leaves on the central portion of the stem, and therefore, the results of the experiment can not be considered conclusive.

Variance analysis of the data showed that the mean yield of leaves per plant in Row 1 was significantly greater than in either of the other rows. Comparison of Row 1 and Row 3 means would seem to indicate that the main stem leaves constitute approximately half of the total leaf yield of a goldenrod plant, the remainder being contributed by the stolon shoots.

Row 2 was significantly higher in leaf yield than Row 3, probably because a portion of the available nutrient material that would normally have been utilized by the plant for stolon production, was diverted into stem growth.

There was no significant difference between the means of the 3 rows in rubber content. This was a rather surprising and unexpected finding, because the presence of comparatively immature stolon leaves in the Row 1 samples would be expected to lower the rubber content materially.

Because of its much higher leaf yield, Row 1 was, of course, significantly higher in yield of rubber per plant than either of the other two rows. Row 2 was also significantly higher in rubber per plant than Row 3.

In an effort to evaluate the effect of stolon shoots on leaf yield and rubber content, correlations between number of stolon shoots

and leaf yield, and between number of stolon shoots and rubber content were calculated. It was found that there was a highly significant position correlation (+ .514) between number of shoots and yield of leaves per plant in Row 1. In the same row there was a significant negative correlation between number of stolon shoots and rubber per cent.

These significant correlations would seem to indicate that a plant having a comparatively large number of stolon shoots would have a relatively high leaf yield and a relatively low rubber content.

However, the latter half of this conclusion is not in agreement with the results of the side by side comparison between Row 1 and Row 2, which indicated that there is no significant difference in rubber per cent between plants with a large number of stolon shoots, and plants of the same clone with no stolon shoots at all.

A similar experiment was conducted in 1940 (Experiment #4002) but a large percentage of the plants were killed by disease, and stolon growth was definitely abnormal among the surviving individuals. Therefore the results can not be relied on to furnish accurate information.

Further investigation of the causes of clonal diversity would seem to be desirable.

TABLE I

Mean yield of dry leaves per plant, mean rubber per cent and mean yield of rubber per plant of entire plants (Row 1) main stems whose stolon shoots were not allowed to develop (Row 2) and main stems whose stolon shoots had developed normally (Row 3), S. leavenworthii 573-C. Experiment #904 Harvested September 19, 1939.

	Row 1	Row 2	Row 3	Difference Necessary for 5% Significance
Leaf Yield (Gms.)	12.28	7.65	5.86	1.45
Rubber Per Cent	4.75	4.87	4.93	0.31
Rubber Per Plant (gms.)	0.584	0.375	0.289	0.073

INSECTS AND DISEASE

Cultivated goldenrod is attacked by relatively few insects, and is

resistant to most of the common pathogenic micro-organisms. There are only two diseases that actually kill the plants, and under ordinary conditions they are not sufficiently virulent to reduce yields materially.

Among the insects affecting goldenrod there are at least two species of Lepidopterous stem borers, which hollow out the center of the stem while in the larval stage. Eggs are deposited inside the stem by the adult which bores a very minute hole in the stem a few inches below the terminal. When the eggs hatch, the larva feeds on the pith, usually consuming 1 to 3 inches of it. This causes temporary wilting and drooping of the tender terminal growth, but the plant usually recovers from this and makes comparatively normal growth. In some instances, however, the stem is so weakened by the activities of the larva, that it breaks off. When that happens, numerous branches are developed just below the break, and growth is resumed. Such plants, of course, never attain normal stature, but their yield is not materially reduced.

These insects are more prevalent some seasons than others, but in any case the damage they cause is of little consequence.

Common aphids may also be listed among the minor pests of goldenrod, and on rare occasions when conditions are exceptionally favorable for their development, they may become abundant enough to check plant growth slightly. They have proved to be a more serious pest on greenhouse grown goldenrod plants, where nicotine sprays are regularly employed to control them. However, it has been very rarely necessary to resort to control measures to reduce the aphid population on field plantings.

During unusually dry weather red spiders sometimes attack goldenrod, but ordinarily are not sufficiently numerous to cause serious damage. Goldenrod plants usually survive red spider damage with only a temporary growth check, but in a few instances the infestation has been severe enough to warrant control measures. It has been found that sulphur dust applied to the under sides of the leaves controls red spiders effectively.

Almost all the species of goldenrod investigated at the Savannah station have proved more or less susceptible to the so-called "scab" disease. This disease is caused by a fungus of the ascomycete class, identified as <u>Elsinoe Solidaginis</u> (2) (3).

Note: (2) Jenkins, A. E. and Ukkelberg H. G.
"Scab of Goldenrod caused by Elsinoe"
Jour. Agr. Research. Vol. 51, No. 6, Pp. 515-525

(3) Jenkins, A.E., Polhamus, L.G. and Hill, H.H.
"New Hosts and Distribution of Elsinoe Solidaginis"
Phytopathology Vol. 29, No. 11, PP. 970-973

Plants may become infected at any stage of development, and are often partially defoliated. Young plants are ocassionally killed and larger plants are definitely stunted. Very characteristic corky lesions are formed, principally on leaves, branches and inflorescences, and in severe cases a considerable portion of the main stem is sometimes completely girdled.

Fortunately only the species which are of minor importance from a rubber producing standpoint are highly susceptible to this disease. Among the less resistant species are S. sempervirens, S. fistulosa, S. serotina, S. edisoniana and S. ulmifolia.

S. leavenworthii is almost never affected by scab, and in the few cases where infection has been found on this species, damage has been negligible.

Scab may be effectively controlled by the use of lime sulphur spray or sulphur dust. In one experiment where 82 per cent of the untreated control plants were infected with scab, only 1.1 per cent of the lime-sulphur sprayed plants were affected and only 6.7 per cent of plants dusted with sulphur contracted the disease. Plants used in this experiment were of the serotina species, which is extremely susceptible to scab. Very little foliage burning was observed on lime-sulphur sprayed plants and the leaves of dusted plants were not injured at all.

"Blight", or "Root-Rot", as it is sometimes called, is the only known disease that is capable of causing serious losses among all cultivated species of goldenrod. In very unfavorable seasons, this disease may cause as high as 15% reduction of stands.

The causal organism is not definitely known, since both fusarium fungus and nematodes are usually present in the diseased tissue.

The fusarium is thought to be the primary invader, and the nematodes secondary, but this theory is by no means definitely established.

In affected plants the first sign of injury ordinarily noticed is a brownish discoloration of the stem just above the ground level. In reality, this symptom indicates an advanced stage of the disease, because the roots are attacked first, and are almost entirely killed before the brown discoloration shows above ground.

The leaves usually begin to wilt and turn yellow soon after the first stem symptoms are noticed, and death of the plant ordinarily occurs a few days later. Occasionally plants survive with the roots almost entirely destroyed, but this is not a common occurrence.

A distinctive characteristic of the disease is its tendency to be

confined to certain areas, roughly circular in outline. All the plants within one of these areas, regardless of species or variety, will be killed, while plants a few inches outside the boundary of the area will be unaffected.

Dry weather is apparently favorable for the spread of this disease, and very few cases of new infection have been observed during periods of ample rainfall.

The characteristic swellings, or root knots commonly caused by nematodes in the plants they attack, are conspicuously absent in blighted goldenrod plants.

This fact would seem to lend support to the belief that the nematodes are secondary, and not the causal organism. There is no control for this disease.

The only other disease of consequence that has been observed on goldenrod is commonly known as "Blossom Blight".

It is thought to be caused by a species of fusarium, but this fact has not been definitely established. Injury caused by this disease is confined to the inflorescence, and it does not affect the general vigor or yield of the plants.

Symptoms of infection are failure of flowers to open normally, and brown discoloration of corolla and reproductive organs. This discoloration, and also distortion, has been observed on very young flower buds as well as mature flowers.

A notable characteristic of blossom blight is that no greenhouse grown plants have ever been affected, even though no precautions have been taken to prevent its spread from field to greenhouse. For this reason most of the goldenrod breeding work has had to be done in the greenhouse.

Since goldenrod does not breed true to type when sexually propagated, the production of a seed crop is of no importance. So even though blossom blight prevents development of good seed in some seasons, it is of no consequence from a rubber production standpoint.

Control measures have not been attempted.

LEAF MATURITY

Experiments were conducted in both 1935 ~~and~~ 1936 for the purpose of ascertaining whether or not there was any relation between leaf age and rubber content.

The age of every leaf on the plants tested, was recorded to the nearest week and all were harvested simultaneously. The leaves were then grouped according to the week in which they were produced, and each group constituted a sample for separate analysis.

In harvesting the 1935 experiment, the dead leaves at the base of the plants were not included in the samples. A highly significant correlation (.943) between leaf age and rubber percent was found.

However, in harvesting the 1936 experiment, all leaves, both dead and green, were included and consequently the rubber content of the samples of old leaves near the base of the plant, was low, because of the high percentage of non-rubber-bearing dead leaves included in such samples.

For SOLIDAGO leavenworthii 3S-92, in 1935, the oldest leaves taken, that is, those which were twenty-one weeks old when harvested, had a rubber content of 8.26 per cent, while the youngest leaves, which were eight weeks old at harvest time, had a rubber content of 1.65 percent.

In 1936 (Solidago Leavenworthii, 573-M) the oldest sample which could be considered comparable to the 1935 samples (i.e. contained less than 3 per cent dead leaves) was 17 weeks old at harvest time, and had a rubber content of 10.13 per cent. The youngest sample was 12 weeks old when harvested and had a rubber content of 6.46 per cent.

It may be concluded, then, that in the 2 selections of Solidago leavenworthii tested, there is a constant and significant increase in the rubber content of green leaves in direct proportion to increased age.

Four other less important species of Solidago, S. altissima, S. fistulosa, S. serotina and S. adisoniana, were included in the 1936 Leaf Maturity Experiments, and in every case the results were very similar to those reported for S. leavenworthii, although the rubber percentages were quite low.

PERFORMANCE OF SELECTIONS COMPARED WITH PERFORMANCE OF THE ORIGINAL SINGLE PLANT--

A study of the rubber content and leaf yield of clones propagated from a single plant, indicates that there is a high correlation between the rubber content of the original plant, and the rubber content of bulk samples of its vegetative increase.

The correlation between the rubber content of 18 single plants

selected in 1936 and the clones grown from these plants in 1937 was + .765. A comparable correlation between twenty-seven 1938 single plant selections and their 1939 increase was + .583. Both of these figures are significant beyond 1% point.

Apparently it is safe to assume that individual seedlings which have a high rubber content, will, when vegetatively propagated, produce clones that are also high in rubber content.

Similar correlations were also calculated for leaf yield, and the relationship is apparently not so constant as rubber content.

The correlation between the 1936 selections and their 1937 clones was + .687, while the comparable correlation for 1938 and 1939 was only + .227. This latter figure is not significant and even though the .687 correlation is highly significant, it is obvious that leaf yield can not be considered as good a criterion as rubber content for selecting individual plants.

PRUNING

In 1935 plants of 2 selections of Solidago leavenworthii and a selection of S. nashii were cut back to the ground level 1 month and 2 months after planting, to determine the effects of drastic pruning.

It was found that plants so treated did not equal the unpruned control plants in size at the end of the growing season, and it was concluded that such treatment was in no way beneficial.

In 1936 an experiment with Solidago leavenworthii, S. edisoniana, S. fistulosa, S. altissima and S. serotina indicated that unpruned plants were significantly higher in both yield of leaves per plant and yield of rubber per plant than plants which were cut back to the ground level at planting time.

EFFECT OF LIGHT ON LEAVES IN STORAGE

An experiment was conducted in 1935 for the purpose of determining the effect of light exposure on the rubber content of harvested leaves.

Leaves of three species(leavenworthii, altissima and serotina)were placed in series of differently colored cellophane bags and exposed to full sunlight for periods ranging from 1 to 3 weeks. Some leaves of each type were enclosed in light-proof black bags as a control.

Results could not be interpreted statistically because there were no replications of the various treatments, but the experiment furnished strong evidence that exposure to light decreases rubber content.

In 10 of the 12 series tested, leaves stored in clear bags had a lower rubber content at the end of the exposure period than those stored in colored or black bags. In 9 series out of 12, the leaves stored in black bags had a higher rubber content than any others at the end of the exposure period.

Because of the poor design of this experiment, the results are inconclusive, but tend to corroborate findings of other investigators in this field.

All available evidence seems to point to the necessity of storing goldenrod leaves in light-proof containers, if serious rubber losses are to be avoided.

COMPARISON OF STEM LEAVES AND BRANCH LEAVES

An experiment with S. leavenworthii showed that the stem leaves contained more than 3 times as much rubber as the branch leaves. This difference was principally due to higher rubber per cent rather than great-weight of leaves produced, although the stem leaves also had a significant advantage in the latter characteristic.

INFLUENCE OF BRANCH LENGTH ON RUBBER YIELD

Study of the relation between branch length and yield indicated that there was a very high positive correlation between total length of all branches of a plant, and the net yield of leaves of the plant. This correlation was found to be + .932.

The correlation between total branch length and yield of rubber per plant was also very high (+ .857).

Conversely, it was found that plants having a high total branch length tend to have a low rubber content. The correlation between these two characters in the series investigated was found to be -.578, a highly significant figure.

The evidence of this experiment would indicate that plants having numerous, large branches tend to yield relatively large quantities of leaves, bearing little rubber.

INFLUENCE OF SOIL P_H ON YIELD AND RUBBER CONTENT

In order to determine the effect of soil PH on goldenrod rubber yield, an experiment was conducted in 1940, in which goldenrod was grown on blocks that had been limed at various rates; and also on adjacent blocks to which no lime had been applied.

The lime was broadcast on the treated blocks and thoroughly incorporated into the soil, about 1 month before the plants were set out. Commercial hydrated lime was used, and rates of application from 1 ton per acre to 4 tons per acre, were tried. Untreated control blocks were arranged alternately with the treated blocks. Four replications of each type of treatment were grown, but the randomization plan was not followed.

Soil samples were taken every 30 days during the test period from April 23 to August 30, and PH determinations were made electrometrically.

In order to obtain representative samples, the following technique was employed. Approximately 1 to 1-1/2 inches of topsoil scraped away to expose the moist earth, and 20 to 30 grams taken. This process repeated 4 times in each plot, and the 4 samples put together in one container and thoroughly mixed. The four were all taken near the center of the plot to avoid possible border effect, or overlapping of treatment from an adjacent plot. Solutions for electrometric testing were prepared by placing 8 c.c. (by volume) of the sample in a test tube with 15 m.l. of distilled water and allowing to stand overnight. The liquid was decanted off and tested the following day.

Statistical analysis of the PH data indicated that all of the lime applications tried in this experiment, increased the PH of the soil significantly (See Table I).

The PH of the untreated blocks (mean of tests on 5 dates, April to August) was 5.98, while the mean PH of the block receiving 1 ton of lime was 6.58, a significant difference. The 2 ton block, with a mean for the test period, of 7.01, was significantly higher than the 1 ton block.

However, there was no significant difference between the 2, 3 and 4 ton blocks, so it would appear that lime applications in excess of 2 tons per acre are no more effective than a 2 ton treatment for raising PH.

The data were also studied to determine whether the PH increases brought about by the lime application were maintained throughout the growing season, or whether leaching, oxidation, or other natural processes caused some change. For some undetermined reason there was a slight, but not consistent increase in PH during the season, the June, July and August tests being somewhat higher than those taken in April and May. Even though these differences were not statistically significant the fact that PH did not decrease with the increase of elapsed time after lime application would seem to indicate definitely that lime is not being leached away.

Statistical analysis of leaf yield and rubber content data showed conclusively that a change in soil PH affects these two characters.

TABLE I

Mean PH of Unlimed Blocks and Blocks receiving Specified Lime Applications, as Tested on 5 Different Dates in 1940. S. leavenworthii, 3S-91. Experiment #4007.

	I Ton Per Acre	2 Tons Per Acre	3 Tons Per Acre	4 Tons Per Acre	Unlimed Blocks
April	6.35	6.92	6.98	6.92	5.65
May	6.40	6.78	6.88	7.20	5.55
June	6.72	7.10	7.38	7.45	6.05
July	6.62	6.95	7.12	7.52	6.08
August	6.80	7.28	7.50	7.45	6.55
Mean	6.58	7.01	7.17	7.31	5.98

Difference between Means necessary for:

5% Significance = 0.36

1% Significance = 0.49

In analyzing these data statistically the leaf yield of each plot was paired with the mean yield of the two adjacent control plots, and the mean difference and standard error calculated. The T test provided a measure of significance for this type of comparison, and T was found to have a value of 3.34, indicating a highly significant mean difference in favor of the untreated plots. So it is safe to conclude that the use of lime reduced net yield of dry leaves per plant.

Rubber content was affected in exactly the opposite manner by the increase in PH. The comparable T value for the rubber content comparison was 4.30, also a very highly significant figure, but in this case it was the treated plots which were higher.

These two effects tend to neutralize each other, and the net result was that no significant difference in rubber per plant could be found.

It would appear from the foregoing that a neutral or slightly alkaline soil tends to produce relatively low yielding plants with high

rubber content, while a more acid soil produces more luxuriant vegetative growth at the expense of rubber content.

The net yield of rubber per acre is apparently not influenced by soil PH within the range encountered in this experiment.

EFFECT OF PHOTOPERIOD ON GROWING PLANTS

In order to investigate the effects of a shorter than normal period of daily sunlight exposure, an experiment was carried out in which a number of goldenrod plants were covered with a lightproof box during part of the day, while an equal number of plants were left uncovered as a control.

The box was placed on the plants each day at 4:00 P.M. and removed at 8:00 AM the following morning. These plants, of course, were in darkness 16 hours of the 24, while the normal dark period at this season is 9 or 10 hours.

The experiment was begun on July 20, during the middle of the growing season. The plants were healthy and normal at the beginning of the experiment, and were about 130 cm. in height.

Within two weeks after the daily covering was started it was observed that the shorter photoperiod had already begun to accelerate sexual maturity. The covered plants were in the juvenile bud stage on August 3 while the untreated control plants were still in the growth stage.

By August 17, the covered plants were in the mature bud stage while the control plants still had not developed beyond the growth stage.

Beyond this point, stages of sexual development could not be determined because excessive heat under the closed boxes/burned the inflorescences so that they did not grow normally.

However, the changes induced up to August 17th were so marked that the conclusion that shortening the photoperiod speeds up floral development is probably a valid one.

Another result of light restriction is inhibition of main stem elongation. The mean increase in height of the covered plants during the test period was only 1.5 cm, while the mean increase of the controls was 47.0 cm. This difference in growth rate is very highly significant.

A shorter light period tends also to reduce loss of lower leaves. It was found that the per cent bare (mean of measurements at 14 day intervals during the test period July 20-September 15) was significantly lower on covered plants than for untreated controls.

There was no significant difference between covered plants and controls in either rubber per cent or rubber per plant.

No controlled experiments, other than the one described above, have been conducted at Savannah. However, potted goldenrod plants growing in the greenhouse have also been covered with lightproof boxes, and a similar acceleration of sexual maturity has been noted. Plants of 3 varieties so treated were found to be in the early bloom stage on September 5, while other greenhouse plants of the same 3 varieties were in the juvenile bud stage.

RELATIVE YIELDS AND MOISTURE CONTENT OF LEAVES & STEMS

In connection with the general study of the characteristics of the goldenrod plant, information has been obtained on the relation of leaf weight to total plant weight, and also the percentages of moisture contained in both leaves and stems.

Leaf and stem percentages have been determined and moisture content calculated, for five leading varieties of S. leavenworthii. All data were obtained in late September or early October when the plants were relatively mature, but had not suffered any severe loss of lower leaves.

Controlled experiments have not been carried out to compare leaf percentages and moisture content of first year plants with those harvested the second year after planting, but data are available from both types of planting, and there is apparently very little difference.

Leaf and stem percentages were all calculated on a green weight basis, and were determined by weighing a freshly cut sample before the leaves were removed, and then weighing the stems after the leaves had been taken off. Leaf weight was obtained by subtraction of stem weight from gross weight.

For moisture content determinations, both stems and leaves were weighed green, and then oven dried to constant weight.

From the data of Table 1 it is apparent that leaves comprise approximately one-fourth of total green plant weight.

About two-thirds of green leaf weight is moisture, while stems have a larger proportion of solid matter and contain only a little more than 50% moisture.

TABLE I

Leaf and stem percentages and moisture content of *S. leavenworthii* 573-c, in experiment #701, and four designated varieties of the same species in experiment #4005 all figures based on green weight.

Variety	Leaf Percentage	Stem Percentage	Per Cent Moisture in Leaves	Stems
573-c	26.04	73.96	66.93	52.00
3S-91	21.29	78.71	59.68	53.92
4S-4	26.52	73.48	60.75	54.68
3S-40	22.93	77.07	64.85	55.38
3S-79	25.34	74.66	67.53	53.75

*Note: Figures for experiment #701 represent mean of 20 samples harvested first season after planting, and figures for each variety in experiment #4005 represent mean of 25 samples harvested second year after planting.

Yield in Pounds of Rubber Per Acre of all Large Samples (24 sq. ft. or more) Taken at Savannah 1936 - 1940 Inclusive

Year Harvested	Expt. No.	Variety	Size of Sample	Rubber Per Acre (Lbs.)	Remarks
1936	621	573-E	150 Sq.Ft.	79.61	Mean of 8 different spacings.
1937	701	573-C	48 Sq.Ft.	55.70	8" spacing. Mean of 5 replications
1937	701	573-C	48 Sq.Ft.	46.67	16" spacing. Mean of 5 replications.
1937	703	573-E	150 Sq.Ft.	55.32	Sampled 18 Mo. after planting. Mean of 4 unthinned plots.
1937	703	573-E	150 Sq.Ft.	36.49	Sampled 18 Mo. after planting. Mean of 8 thinned plots.
1938	802	573-M	24 Sq.Ft.	77.98	Sampled 18 Mo. after planting. Mean of 4 unthinned plots.
1938	802	573-M	24 Sq.Ft.	65.11	Sampled 18 Mo. after planting. Mean of 8 thinned plots.
1938	802	573-M	24 Sq.Ft.	43.60	Mean of 4 first season plots.
1938	803	573-C	32 Sq.Ft.	55.60	24x8 In.spacing.Mean of 4 replications.
1938	803	573-C	40 Sq.Ft.	51.67	30 x 8 In. spacing. Mean of 4 replications.
1939	901	573-M	24 Sq.Ft.	66.65	Sampled 30 Mo. after planting. Mean of 4 unthinned plots.
1939	901	573-M	24 Sq.Ft.	31.31	Sampled 30 Mo. after planting. Mean of 8 thinned plots.
1939	901	573-M	24 Sq.Ft.	71.26	Sampled 18 Mo. after planting. Mean of 4 unthinned plots.
1939	903	3S-91	50 Sq.Ft.	27.95	Mean of 30 replications.
1939	903	3S- 4	50 Sq.Ft.	36.97	Mean of 30 replications.
1939	903	3S-40	50 Sq.Ft.	34.19	Mean of 30 replications.
1939	903	3S-79	50 Sq.Ft.	44.85	Mean of 30 replications.
1940	4005	3S-91	50 Sq.Ft.	47.78	Mean of 25 replications.
1940	4005	3S- 4	50 Sq.Ft.	46.78	Mean of 25 replications.
1940	4005	3S-40	50 Sq.Ft.	51.99	Mean of 25 replications.
1940	4005	3S-79	50 Sq.Ft.	50.06	Mean of 25 replications.
1940	4008	3S-79	50 Sq.Ft.	60.12	Mean of 7 replications.